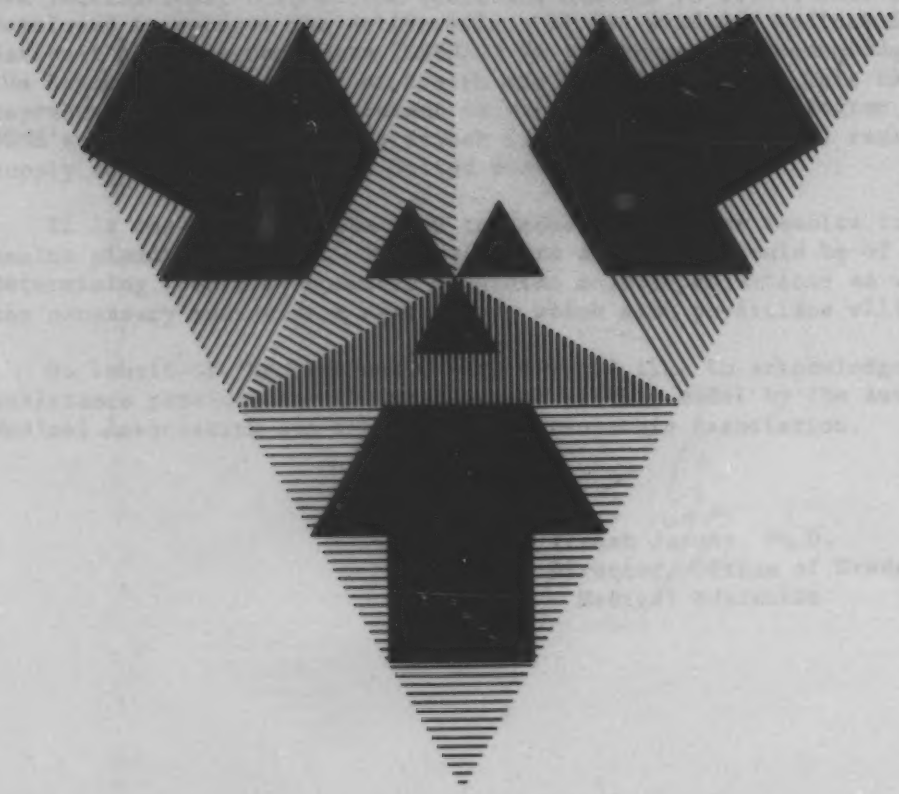
Model for Estimating Physician Supply in 1990



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FOREWORD

This report, "Model for Estimating Physician Supply in 1990," was developed to forecast supply and specialty distribution of active physicians in the United States in 1990. Developed for the Office of Graduate Medical Education (OGME), Health Resources Administration, by JWK International Corporation (contract HRA 232-79-0094), this model was developed to support the deliberations of the Graduate Medical Education National Advisory Committee (GMENAC) in preparing its recommendations to the Secretary, Department of Health and Human Services. This report represents a significant element in an ongoing research program of the OGME's Research and Analysis Branch (Jerald Katzoff, Chief) regarding the supply of physicians in the United States.

It is the intent of the OGME to incorporate these results into the health planning process. The model here described should be of value in determining specialty-specific physician supply projections as well as the necessary educational system from which such physicians will graduate.

On behalf of the OGME and GMENAC I would like to acknowledge the assistance provided for the development of this model by the American Medical Association and the American Osteopathic Association.

Itzhak Jacoby, Ph.D.
Director, Office of Graduate
Medical Education

Acknowledgements

JWK International Corporation acknowledges the assistance of the following agencies and individuals in providing information used to develop data and assumptions used in these supply projections:

- American Medical Association Data Release Center for supply of M.D.'s as of December 31, 1978.
- American Osteopathic Association, Kellogg Project, Task Force on Osteopathic Graduate Medical Education for supply of D.O.'s as of 1979 and projections for 1988-89.
- Association of American Medical Colleges for information on U.S. medical school admissions.
- Executive Director of the Educational Commission for Foreign Medical Graduates for information on foreign medical graduates.
- Executive Director of the National Resident Matching Program for information on residency selection and tracking of residents.
- Secretary of the Liaison Committee on Medical Education for information on first-year enrollment in U.S. medical schools.
- Division of Health Professions Analysis, Health Resources Administration, DHHS, for information on the SOAR program.
- National Center for Education Statistics for comparative data on medical school enrollment and graduates.
- Office of Graduate Medical Education, Health Resources Administration for updated data on Internal Medicine fellowships.

JWK International Corporation further thanks Dr. Itzhak Jacoby, Director of the Office of Graduate Medical Education and Mr. Jerald Katzoff, Project Officer for their support and direction of this study.

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Executive Summary

This report describes a model for projecting the supply of active physicians in the United States and then applies the model to forecast the number of doctors, by specialty, in 1990.

The total supply of practicing physicians depends chiefly on the size of U.S. medical school enrollments, while the number of practitioners in various specialties is governed by how many medical graduates enter each residency program and how many change specialties during and after graduate training. The details of the relationship between input and supply are complex. In addition to graduates of U.S. medical schools, the input to residency programs is augmented by U.S. citizens who attend foreign medical schools and return to the U.S., and by foreign medical graduates who immigrate to the U.S. Graduates of osteopathic schools who elect allopathic residencies also contribute to this number.[1]

Residency outputs, however, are not identical to their inputs. Once in a program, a physician may subspecialize, or change to an entirely different residency, or change practice area after completing specialty training.

Once residents complete their programs and enter practice, they add to the size of the pools of active specialists. Simultaneously, these pools are being depleted by retirement, death, or permanent withdrawal from practice. Each specialty pool is, therefore, in constant flux, with new doctors entering each year as others leave.

The second factor influencing supply projection is the increasing enrollments in U.S. medical schools which are expected to continue. Growth means that the pool of practicing physicians is becoming younger on the average, which in turn implies that the fraction of the pool lost each year to death and retirement is declining. Therefore, growth is accelerating, with more physicians entering practice and smaller fractions of those in practice leaving. As a result, the 356,000 physicians in active practice in 1978 will increase more than 40 percent to 505,000 by 1990 (residents are excluded in both figures).[2]

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[1] Osteopaths who go through osteopathic residency programs are included in the total supply projection, but the number of these physicians is not projected through the model developed in this project due to the lack of appropriate input data.

[2] These supply figures include both allopathic and osteopathic physicians.

All specialties are not expected to share equally in this growth. While general pediatrics is expected to increase by more than 50 percent, other specialties such as psychiatry will be only a little larger than they were in 1978. This inconsistency in growth among specialties may lead to problems in the supply of certain crucial medical services.

The supply model described below was designed to study such problems. Federal officials concerned with health care planning have policy options at their disposal which enable them to influence the supply of medical specialists. They can offer financial encouragement to doctors entering some programs to encourage growth, but, to be effective such incentives must have predictable results.

The supply model (and its adjuncts) described here can assist health care planners in choosing appropriate options in two ways. First, it can predict the future size of specialty pools based on assumptions about the size of medical school enrollments, residency choices, retirement rates, and so on. Second, it can determine what changes in inputs might be necessary to meet certain supply goals which differ from the supply predicted for any given future year (e.g. 1990 or 2000). Thus, the model functions both prospectively -- to forecast the results of certain assumed trends (such as continued growth in enrollment) -- and retrospectively -- to show how these trends might be altered to achieve desired increases or decreases in the specialty pools.

Using the model in this way has already provided insights which are important and useful for planning. Results derived from the model show that the physician supply system has great "inertia." It is virtually impossible to change the size of specialty pools by short-term manipulation of either medical school enrollments or the size of residency programs. For instance, very little can be done between now and 1990 which would change the supply of specialists in 1990. This inertia (or slowness to respond) results from several factors. First, the active practice pools of each specialty are large compared to the output of the residencies which supply them. Second, most residencies extend over a fairly long period of time (4 to 5 years on the average). Together these two conditions mean that nearly all the physicians who will form the active pools of most specialties in 1990 are either in practice or currently in residency training.

This lag means that planners must consider long lead times to achieve a particular supply of specialists. There will be natural "drift" in the system resulting from extrinsic conditions which cannot now be predicted or controlled. As a result, continual readjustment of the system through changing incentives will be necessary to attain specific supply goals. For example, if the advent of National Health Insurance prompts a change in anticipated physician behavior (e.g. out-migration), then supply forecasts will be dramatically altered.

The strength of this Integrated Physician Supply Model lies in its conceptualization as a system that captures the flow of individuals through

the continuum of medical education -- both undergraduate and graduate.[1] As such, the supply estimates produced are probably closer to reality than previous estimates and can be valuably used by decision-makers in weighing policy options and directions.

[1] In this report undergraduate refers to the 4 years of medical school and graduate refers to period of graduate medical education or residency.

Specialty Code Abbreviations

A	Allergy
AI	Allergy and Immunology
AM	Aerospace Medicine
CD	Cardiovascular Diseases
CHP	Child Psychiatry
CRS	Colon and Rectal Surgery
D	Dermatology
DIA	Diabetes
DR	Diagnostic Radiology
END	Endocrinology
FOP	Forensic Pathology
GE	Gastroenterology
GER	Geriatrics
GP	General Practice
GPM	General Preventive Medicine
GS	General Surgery
HEM	Hematology
ID	Infectious Diseases
IG	Immunology
IM	Internal Medicine
N	Neurology
ND	Neoplastic Diseases
NEP	Nephrology
NS	Neurological Surgery
NTR	Nutrition
OBG	Obstetrics and Gynecology
ON	Oncology
OPH	Ophthalmology
ORS	Orthopedic Surgery
OTO	Otorhinolaryngology
P	Psychiatry
PD	Pediatrics
PDA	Pediatric Allergy
PDC	Pediatric Cardiology
PH	Public Health
PM	Physical Medicine and Rehabilitation
PS	Plastic Surgery
PTH	Pathology
PUD	Pulmonary Diseases
R	Radiology
RHU	Rheumatology
TR	Therapeutic Radiology
TS	Thoracic Surgery
U	Urology
OS	Other Specialties
US	Unspecified

1. INTRODUCTION

This document describes the model for projecting the supply of active physicians developed by JWK International Corporation for the Office of Graduate Medical Education, Health Resources Administration, Department of Health and Human Services under contract No. HRA-232-79-0094.

In 1978, 96 percent of all physicians in active practice in the United States were trained in allopathic medicine (M.D.'s); the rest were trained in osteopathic medicine (D.O.'s). This suggests that any projection of future supply of physicians is influenced significantly by the characteristics of the current supply and the trends and changes in the training of M.D.'s. For this reason, the supply projection model developed in this project was built using the best available data on the age, sex, and specialty practice of the current supply of M.D.'s; and on the pattern of educational experience of undergraduate and graduate medical students.

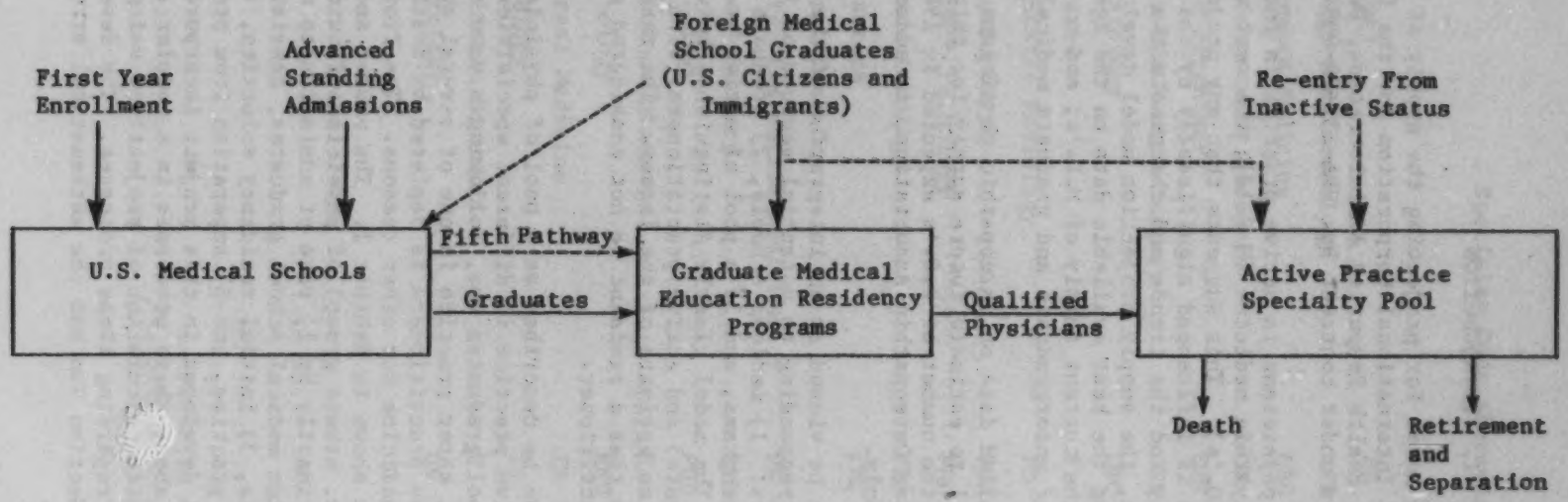
The lack of comparably detailed data on osteopathic physicians precluded the application of the model to estimate future supply for this group. Therefore, the estimate of the number of D.O.'s expected in 1989, which was developed by the American Osteopathic Association, is added to the projections of the M.D. supply.

Conceptually, the model can be viewed as an integration of the input and output of three modules corresponding to potential sources of future supply of practicing physicians: 1) medical schools, 2) graduate medical education (GME) residency programs, and 3) a pool of active practitioners during a baseline period. The model clearly distinguishes between physicians in training (residents) and active practitioners, with the supply projection based on an estimate of the latter. The rationale underlying this decision is that a resident is not considered a full-time equivalent of an active practitioner.

The supply of physicians can be described as a pool of physicians of different ages who are in active practice in different specialties. This pool is fed by medical school graduates who, following a year or more of graduate medical education, enter practice in one of several specialties. Each year the pool of active practitioners is depleted by deaths, retirements or separations from medicine for other reasons. The flow of M.D.'s through the supply model is shown in Exhibit 1. The number and characteristics (age, sex, specialty, ethnic group) of physicians flowing through the model are controlled primarily by 1) rate of admission to medical schools, 2) influx of foreign medical school graduates, consisting of U.S. citizens and immigrants, 3) initial residency selection, 4) specialty shifts during training and practice, and 5) separation from practice for whatever causes. The model developed in this project incorporated the best available information about these processes in a modular sequence. The logic of the model permits calculation of projections using any combination of assumptions regarding these processes. The development of the model is described in Section Two and the mathematical structure is discussed in Section Three.

EXHIBIT 1

FLOW OF M.D.'S THROUGH THE INTEGRATED PHYSICIAN SUPPLY MODEL (IPSM)



2. DEVELOPMENT OF AN INTEGRATED PHYSICIAN SUPPLY MODEL (IPSM)

Recent work supported by the Health Resources Administration (HRA) of the Department of Health and Human Services (DHHS) has resulted in a better understanding of the processes that govern the supply of physicians. However, these efforts have been disparate and have not produced a coherent model which integrates all processes and is simple enough to permit testing of different assumptions regarding changes in medical education. The Supply Model developed by the Bureau of Health Professions (SOAR), for example, projects physician supply in two disconnected calculations: 1) estimation of the aggregate supply of physicians without distinction between those in training and in practice, and 2) estimation of the percent distribution of medical specialties in the projection period. A graduate medical education model developed at Johns Hopkins University estimates the number of residents in training in 39 specialties. Finally, a branching and switching study of physicians, conducted for the Office of Graduate Medical Education, developed transition probabilities for interspecialty shifts during and after residency training, and output probabilities for projecting the number of residents going into practice over several years following graduation from medical school.

The current effort integrated the best features of the above models into a simplified, but highly flexible model. The modular design of this model permits calculation at a very detailed level depending on the availability of input data. As stated earlier, there are three sequential modules: 1) medical school, 2) graduate medical education, and 3) active practice — each of which has specific inputs and outputs. The output of the first module serves as input to the second, and the output of the second serves as input to the third. The specificity of the input is constrained only by the availability of reliable data. Each of the modules is described below.

Module 1: Medical School

Minimum input data required for running this module are:

1. First year enrollment
2. Sex distribution
3. Completion rate
4. Growth rate over the projection period.

The module is designed to accept input data by medical schools. It is also designed to compute ethnic distribution. The current version, however, does not compute projection by school and does not include ethnic distribution of enrollment due to the lack of sufficiently accurate data. Although we

were able to obtain enrollment by school with ethnic and sex distributions, we were unable to obtain completion rates by sex or by ethnic group. Several data sources were contacted; these were the Association of American Medical Colleges (AAMC), American Medical Association, Liaison Committee on Medical Education (AMA, LCME) and the National Center for Education Statistics (NCES) of the Office of Education.

NCES is the only agency that gathers statistical information on sex and ethnic distributions of first year enrollees and medical school graduates on a school-by-school basis. However, these data are gathered only on an alternate year cycle and do not provide an accurate measure of completion rates.

Some discrepancies were found among enrollment and graduate figures reported by the different agencies. This is most likely due to the difference in the time period covered in the reporting. AAMC's data on enrollment, for example, are gathered in the fall of each school year; AMA's data are completed in the summer of the following year; NCES data are reported for those enrolled during the fall term. To assure the use of accurate data for the purpose of projections, reports were compared on a school-by-school basis. Total first year enrollment reported by AAMC for the 1978-1979 school year for 124 schools was 16,501. This is comparable to the 16,600 figure reported by AMA for the same schools (99.4 percent agreement). However, when figures are compared for each school, differences were noted in 55 of the 124 schools. Similarly, the numbers and sex distribution of medical school graduates reported by NCES and AMA do not agree on a school-by-school basis, and discrepancies were quite large for some schools. For example, for one school NCES reported 67 males and 21 female graduates for 1977-78; for the same school and period, AMA reported 52 males and 7 females. School by school differences, however, probably cancel out since totals for all schools agree quite closely, as shown below:

REPORT OF 1977-78 GRADUATES (110 SCHOOLS)

	NCES	AMA
Total	14,399	14,393
Male	11,299	11,307
Female	3,100	3,086

The current version of the model uses available AMA or AAMC data on total first year enrollment as well as AMA data on total medical graduates to estimate the contribution of U.S. medical schools to the graduate medical education pool (the second module in the model). This is feasible because such totals appear to be consistently reported by different agencies when the timing of surveys is adjusted for, and because the model operates adequately using total enrollment or total graduates as inputs. Further discussion of the actual input data and assumptions used in projecting the output of the medical school module is found in Section Four.

Module 2: Graduate Medical Education

This module is the heart of the supply model developed in this project. No other supply model considers the flow of physicians through the GME process and the impact of that flow on the active supply. Since the GME process has the more immediate impact on the number of physicians that will practice in different specialties, determination of the input and output of this module is by far the more critical aspect of relatively short term (10-year) projections.[1]

Residency Input

In addition to the U.S. medical school graduates, which in future years can be estimated from the size of the first year enrollment and an assumed completion rate for each first year cohort, a sizable number of foreign medical school graduates (FMG) enter graduate medical education in the U.S. each year. These graduates include U.S. citizens who have been returning for graduate medical education in increasing numbers in the past few years. While there are no accurate statistics, it has been estimated that 12,000 to 15,000 U.S. citizens are studying medicine abroad, and that approximately 1500 to 2500 will be returning to the U.S. each year for graduate medical education. A very careful review of the SOAR model[2] reveals that it does not include U.S. Citizens in the number of foreign medical school graduates. IPSM, the supply model developed in this project, considers the U.S. citizen component of foreign medical school graduates a significant input to the GME pool and operates on assumptions regarding the size of this pool. Further, IPSM input includes not only estimates of the number of alien FMG physicians that are likely to enter GME and practice in the U.S, but also the number of individuals transferring from foreign medical schools with advanced standing or entering residencies via the "fifth pathway" clerkship.[3] The basis for these estimations is discussed in Section Four.

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1 Preliminary analysis using the model shows that an increase or decrease in medical school enrollment starting in 1979 becomes significant in the year 2,000, not in 1990.

2 The following materials supplied by the Division of Health Professions Analysis, HRA were reviewed.

- Computer program run 3/18/80
- Preliminary Draft, Current and Future Supply of Physicians and Physician Specialists, July 1, 1979.

3 U.S. citizens who have completed medical degrees abroad and return to the U.S. for a year of clinical training before entering a residency program.

Residency Distribution

The GME module takes the input described above and distributes it into different residency programs using a known or assumed pattern of residency selection corresponding to the type of graduate -- U.S. medical school graduate (USMG), Foreign Medical school graduate, (FMG), or entrants via the fifth pathway and other North American Graduates (NAG). This residency selection is reported yearly by the National Resident Matching Program (NRMP). Unlike the LCGME/AMA Directory of Residency Training Programs, the NRMP reports distribution of residents at entry into the first year of graduate medical education (G-1). The Directory reports distribution of positions offered among all first year residencies (R-1) including those that accept residents in the first year of the program only after one or more years of GME; examples are many of the subspecialties such as pediatric cardiology, thoracic surgery, etc.

The NRMP data on G-1 residency selection were used since the GME module projects yearly output of residents entering practice based on the year in which they first entered graduate medical education (G-1). The data were further adjusted to reflect the interspecialty shifts occurring at the G-2 level. Conversion factors used for this adjustment were developed from data collected by the NRMP in its recent tracking study.[1] The table of conversion factors is shown in Exhibit 2. This table is applied to the G-1 specialty distribution in a given year. For example, applying the conversion table to the 1979 medical graduates results in an expected G-2 specialty distribution shown in Exhibit 3.

Output into Practice

Not all medical school graduates entering residency programs in the same year will enter practice at the same time. Neither can it be assumed that all residents choosing a first year of graduate medical education in a specialty will finally practice in that specialty. The GME module in IPSM takes these factors into consideration and uses residency output probabilities to estimate the number of residents who enter practice at a given point in time relative to their year of graduation from medical school or entry into graduate medical education. These residency output probabilities were derived from interspecialty transition probabilities developed in a previous study for the Office of Graduate Medical Education.[2] Exhibit 4 is the transition matrix for general surgery. The numbers in the matrix are the probabilities of going from the positions listed down the left hand side to the positions listed along the top during a one-year

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[1] Graettinger, John D., "A Tracking Study of U.S. Medical School Graduates from the First to the Second Postdoctoral Year." J. Med . Education, Volume 55, August 1980.

[2] Hunt, Leon, Branching and Switching Among Specialties During Graduate Medical Education, Project Research Final Report, 1979, HRA Contract 232-78-9135.

EXHIBIT 2

TABLE OF CONVERSION FACTORS FOR G-1 TO G-2 INTERSPECIALTY SHIFTS [1]

G-1 Specialty \ G-2 Specialty	FM	IM	PD	OBG	D	N	OPH	P	GS	NS	ORS	OTO	UR	AN	PTH	PM	DR	TR
Family Practice	.9425	.0109	.0041	.0102	.0034	-	.0013	.0034	.0061	.0006	.0027	-	-	.0047	.0060	-	.0020	-
Internal Medicine	.0024	.8534	.0026	.0082	.0113	.0113	.0305	.0145	.0062	.0038	.0027	.0004	.0004	.0070	.0077	.0007	.0283	-
Pediatrics	.0041	.0066	.9433	.0008	.0008	-	.0066	.0158	.0025	-	.0017	.0008	-	.0025	.0016	.0008	.0116	-
Obstetrics	.0045	.0045	-	.9592	-	-	.0015	.0030	-	-	.0015	-	-	.0090	.0030	-	.0060	-
Dermatology	-	-	-	-	.8888	-	-	-	-	-	-	-	-	-	-	-	-	-
Neurology	-	.0178	-	-	-	.8571	-	.0357	.0357	.0357	-	-	-	-	-	-	.0178	-
Opthalmology	-	-	-	-	-	-	.9317	.0454	-	-	-	-	-	-	.0227	-	-	-
Psychiatry	.0080	.0302	.0200	-	.0060	.0020	.0020	.9294	.0120	.0020	.0020	-	-	-	.0020	-	-	-
General Surgery	.0014	.0138	.0014	.0072	.0021	.0130	.0101	.0007	.7398	.0159	.0937	.0406	.0109	.0145	.0079	.0007	.0174	-
Neuro Surgery	-	-	-	-	-	.0555	-	-	-	.8888	-	-	-	.0555	-	-	-	-
Orthopedics	-	.0065	-	-	-	.0065	.0065	-	.0196	-	.9346	-	.0065	-	-	-	.0130	-
Otolaryngology	-	-	-	-	-	-	-	-	.0800	-	-	.9200	-	-	-	-	-	-
Urology	-	-	-	-	-	-	-	-	-	-	-	-	.9736	.0263	-	-	-	-
Anesthesia	-	.0270	-	.0108	-	-	.0054	.0054	-	-	-	-	-	.9351	-	-	.0054	-
Pathology	-	.0162	-	.0065	.0032	.0032	.0032	.0097	-	-	-	-	-	.0032	.9413	-	.0130	-
Physical Medicine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.000	-	-
Diagnostic Radiology	-	.0114	.0038	.0038	-	-	.0038	.0038	.0038	-	.0038	-	-	-	-	-	.9655	-
Therapeutic Radiology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.000
Flexible	.0644	.1491	.0377	.0722	.0345	.0157	.1381	.0487	.0675	.0078	.0581	.0173	.0031	.0753	.0204	.0031	.0722	-

[1] Based on NRMP's 1977 Tracking Study.

EXHIBIT 3

EXPECTED G-2 SPECIALTY DISTRIBUTION

1979 USMG's

1979 G-1 Distribution		FP	IM	FD	OBG	D	N	OPH	P	GS	NS	ORS	OTO	UR	AN	PTH	PM	DR	TR
FP	.1393	.1313	.0015	.0006	.0014	.0005	-	.0002	.0005	.0008	.0001	.0004	-	-	.0006	.0008	-	.0003	-
IM	.3565	.0009	.3042	.0009	.0029	.0040	.0047	.0109	.0052	.0022	.0014	.0010	.0001	-	.0025	.0027	.0002	.0101	-
FD	.1022	.0004	.0007	.0964	.0001	.0001	-	.0007	.0016	.0003	-	.0002	.0001	-	.0003	.0002	.0001	.0012	-
OBG	.0618	.0003	.0003	-	.0593	-	-	.0001	.0002	-	-	.0001	-	-	.0005	.0002	-	.0004	-
D	.0002	-	-	-	-	.0002	-	-	-	-	-	-	-	-	-	-	-	-	-
N	.0028	-	.0001	-	-	-	.0024	-	.0001	.0001	.0001	-	-	-	-	-	-	.0001	-
OPH	.0014	-		-	-	-	-	.0013	.0001	-	-	-	-	-	-	.0000	-	-	-
P	.0363	.0003	.0011	.0001	-	.0002	.0001	.0001	.0337	.0004	.0001	.0001	-	-	-	.0001	-	-	-
GS	.1323	.0002	.0018	.0002	.0010	.0003	.0017	.0013	.0001	.0979	.0021	.0124	.0054	.0014	.0019	.0010	.0001	.0023	-
NS	.0022	-	-	-	-	-	.0001	-	-	-	.0019	-	-	-	.0001	-	-	-	-
ORS	.0180	-	.0001	-	-	-	.0001	.0001	-	.0003	-	.0168	-	.0001	-	-	-	.0002	-
OTO	.0022	-	-	-	-	-	-	-	-	.0002	-	-	.0020	-	-	-	-	-	-
UR	.0038	-	-	-	-	-	-	-	-	-	-	-	-	.0037	.0001	-	-	-	-
AN	.0166	-	.0004	-	.0002	-	-	.0001	.0001	-	-	-	-	-	.0155	-	-	.0001	-
PTH	.0232	-	.0004	-	.0001	.0001	.0001	.0001	.0002	-	-	-	-	-	.0001	.0218	-	.0003	-
PM	.0016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.0016	-	-
DR	.0211	-	.0002	.0001	.0001	-	-	.0001	.0001	.0001	-	.0001	-	-	-	-	-	.0204	
TR	.0015	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.0015
FLEX	.0770	.0050	.0115	.0029	.0056	.0026	.0012	.0106	.0037	.0052	.0006	.0045	.0013	.0002	.0058	.0016	.0002	.0055	-
Expected G-2 Distribution		.1384	.3223	.1012	.0707	.0080	.0104	.0256	.0456	.1075	.0063	.0356	.0089	.0054	.0274	.0284	.0022	.0409	.0015

EXHIBIT 4

Transition Matrix for General Surgery (Best Project Estimates)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
MS	1		.99																			.01					
INT*	2			.99																		.01					
GS1	3				.73					.08				.06				.06					.03	.04			
GS2	4					.85				.02				.01				.01					.015	.015	.08		
GS3	5						.78			.005								.005					.06		.15		
GS4	6							.20															.16	.01	.63		
GS5	7								.32														.10		.58		
GS6	8								.35														.06		.59		
ORS1	9										.95															.05		
ORS2	10											.95														.05		
ORS3	11												.84													.16		
ORS4	12																									1.		
OTO1	13														1.													
OTO2	14															1.												
OTO3	15																.10										.90	
OTO4	16																										1.	
U1	17				.02														.97									.01
U2	18																			.95					.01			.04
U3	19				.02																.60							.38
U4	20				.07																.07							.86
UNK	21			1.																								
OSS**	22																						1.					
OS	23																							1.				
PRAC GS	24																								1.			
PRAC ORS	25																									1.		
PRAC OTO	26																										1.	
PRAC U	27																											1.

* Internship may actually be a specialized surgical internship or a first year surgical residency.
**Other surgical specialties are mainly plastic surgery, neurosurgery, thoracic surgery and colon and rectal surgery.

period. For example, if an individual is in a first year general surgery residency, the probability of going to a second year general surgery residency is 0.73; that is, on the average, 73 percent of first year residents have continued to second year residencies in general surgery (See intersect of Row 3 and Column 4, Exhibit 4.)[1] Also 8 percent have gone into orthopedic residencies (intersect of Row 3 and Column 9), 6 percent into otolaryngology residencies, etc.

Using this matrix we calculate how long it takes each physician who began in a general surgery residency to emerge in practice, and also whether he/she will enter general surgery or some other practice area. However, some individuals do not continue in their first practice area, but quickly shift to another. Most of these post-GME practice changes occur within a few years after completing GME, and, in any case, within 10 years after graduation from medical school.

These changes result in the final practice distributions given in Exhibit 5. For example, of all those entering general surgery residencies, 37.6 percent practiced in general surgery, 14 percent in orthopedic surgery, 8 percent in otolaryngology, etc. (see first row in Exhibit 5).

Exhibit 6 shows the output for general surgery residencies in more complete detail by describing the fractions of general surgery residents who appear in practice in both general surgery and in all the other specialties it supplies within 1, 2, 3, . . ., 9 years following graduation from medical school. For instance, of all individuals entering general surgery residencies, 4.6 percent emerge as practicing general surgeons within four years, 7 percent more within five years, etc. The sum of this first row in Exhibit 6 is the same number as is found in the corresponding cell (GS-GS intersect) in Exhibit 5. That is, .046 + .070 + .204 + .035 + .014 + .007 = .376 (or 37.6 percent) which is the total fraction of general surgery residents who finally practice general surgery. Similarly, the sum of the other rows gives the total percentages of general surgery residents who eventually practice in other areas, as in Exhibit 5 (first row).

Module 3: Active Practice

The active practice module operates in a straightforward fashion to incorporate gains and subtract losses, each year, for each separate cohort. The gains are the output of the GME module; the losses are those due to death and retirement or separation for other reasons.

The current version of this module operates with the following minimum data requirements:

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[1] This probability agrees exactly with NRMP's tracking study; See Graettinger, op. cit.

EXHIBIT 5

RESIDENCY INPUT - SPECIALTY OUTPUT DISTRIBUTION
(INCORPORATES RESIDENCY CHANGES AND POST-GME SPECIALTY SWITCHES)

PRACTICE SPECIALTY OUTPUT (SELF-DECLARED) (%)

Residency Inputs	GS	ORS	OTO	U	PS	TS	MS	CRS	IM	CD	PUD	GE	PD	PDA	PDC	OBG	FP	P	CHP	R	DR	TR	OPH	PTH	AN	M	D	AM	PM	OPM	PM	OA	A	ME
GS	37.6	14.0	8.0	10.0	7.0	5.0	5.0	1.0	1.2	0.2		0.1	0.1			1.2	3.8	0.4	0.1	0.7	0.4	0.2	0.8	0.6	1.9	0.1		0.1	0.1	0.2	0.1	0.1		
ORS	2.9	91.3	0.2	0.1	0.1	0.1			0.8								1.5	0.2		0.7	0.2		0.4	0.1	0.6	0.4		0.2	0.2					
OTO	2.0	0.2	91.2		3.0	0.1			0.4								0.7			1.3			0.5	0.2						0.2		0.2		
U	1.0	0.6	0.3	90.4					1.5			0.5	0.4			1.0	1.0	0.5		1.0	0.5		0.5	0.4	0.4									
IM	0.4	0.5	0.3	0.5	0.1		0.1	0.1	60.7	12.3	3.7	5.2	0.4			0.3	2.5	1.4	0.1	1.8	1.2	0.1	1.3	0.5	0.3	2.1	1.7	0.1	0.2	0.1	0.6	0.2	1.2	
PD	0.1	0.3				0.1	0.1		5.7	0.1	0.1	0.7	76.3	1.9	1.6	0.1	1.2	1.7	1.4	0.6	0.6		0.5	0.6	0.6	2.7	0.6			0.5	1.2		0.7	
OBG	0.4	0.2		0.1					0.7				0.2			93.6	1.0	0.2	0.2	0.4		0.1	0.3	0.2	1.8	0.1	1			0.3	0.1		0.1	
FP	1.0	0.7	0.3						2.9	0.3			1.4			1.4	84.1	1.2		1.2	0.7		0.7	0.7	0.7		1.5	0.5			0.7			
P	0.2	0.1			0.1				1.1							0.2	1.9	81.5	12.2	0.2	0.1		0.1	0.8		1.1	0.1	0.1		0.1	0.1			
R		0.2	0.2			0.1			0.6	0.2			0.5			0.1	1.1	0.7		60.5	30.2	5.0	0.1	0.1	0.3						0.1			
DR										0.4			0.6							26.5	69.4	2.1			0.4	0.6								
OPH	0.2		0.1				0.1		0.2				0.2			0.1	0.3	0.4			0.1	0.1	97.5		0.2	0.1	0.1	0.1				0.2		
PTH	0.7	0.1	0.1	0.2					2.1	0.5	0.5	0.1	0.9			0.7	2.1	1.2		1.4	0.4	0.3	0.7	86.1	0.3	0.5	0.4	0.3			0.1			0.3
AM	0.5			0.2			0.4		0.6	0.2	0.2					0.4	2.0	0.7	0.2	0.2	0.2		0.4	0.2	92.5		0.2		0.4		0.5			
M	0.2	0.3					5.0		1.8				0.5				1.2	15.0	1.2	0.9	0.9		3.0	0.8	0.3	68.4	0.2	0.3						

EXHIBIT 6

OUTPUT OF PHYSICIANS ENTERING FIRST YEAR
GENERAL SURGERY RESIDENCY

Probability of Entering Indicated Practice Within the
Nth Year Following Medical School Graduation

Practice Area	Year Following Medical School Graduation								
	n=1	2	3	4	5	6	7	8	9
General Surgery	-	-	-	.046	.070	.204	.035	.014	.007
Orthopedic Surgery	-	-	-	-	.014	.014	.084	.028	-
Otolaryngology	-	-	-	-	-	.057	.023	-	-
Urology	-	-	-	-	-	.033	.067	-	-
Plastic Surgery	-	-	-	-	-	.016	.019	.027	.008
Thoracic Surgery	-	-	-	-	-	.011	.014	.019	.006
Neurological Surgery	-	-	-	-	-	.011	.014	.019	.006
Colon & Rectal Surgery	-	-	-	-	-	.002	.003	.004	.001
Internal Medicine	-	-	-	.001	.009	.001	.001	-	-
Obstetrics/Gynecology	-	-	-	-	.001	.009	.001	.001	-
General/Family Practice	-	.029	.001	.008	-	-	-	-	-
Radiology	-	-	-	-	-	.006	.001	-	-
Opthalmology	-	-	-	-	-	.006	.001	-	-
Pathology	-	-	-	-	-	-	.005	.001	-
Anesthesiology	-	-	-	.010	.009	-	-	-	-
Cardiovascular Diseases	-	-	-	-	-	.001	.001	-	-
Pediatrics	-	-	-	-	.001	-	-	-	-
Psychiatry	-	-	-	.001	.002	.001	-	-	-
Child Psychiatry	-	-	-	-	-	.001	-	-	-
Diagnostic Radiology	-	-	-	-	.001	.002	.001	-	-
Therapeutic Radiology	-	-	-	-	-	.001	.001	-	-
Neurology	-	-	-	-	-	.001	-	-	-
Aerospace Medicine	-	-	-	.001	-	-	-	-	-
Physical Medicine	-	-	-	.001	-	-	-	-	-
General Preventive Medicine	-	-	-	.001	.001	-	-	-	-
Public Health	-	-	-	.001	.001	-	-	-	-
Occupational Medicine	-	-	-	.001	-	-	-	-	-
Gastroenterology	-	-	-	.001	.001	-	-	-	-

- Age and sex distribution for each specialty in a specific baseline period
- Age, sex, and specialty distributions for each output of the GME module
- Death, retirement or separation rates for each sex and age group, corrected for those who may return to active practice from inactive status[1]
- Length of the projection period.

The baseline supply and additions (output of the GME module) are aged yearly for the duration of the projection period, and the net separation rate specific to each sex and age group is applied to determine loss from each specialty. Thus, the model is able to project on a yearly basis the supply of active practitioners in each specialty.

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1 The model currently incorporates the separation rates for male and female physicians developed in the SOAR project.

3. MATHEMATICAL STRUCTURE OF THE IPMS MODEL

The physician supply process is represented by a model which computes changes to the pool of active practitioners each year. (In mathematical terms, the current version of the model is a 9th order system of difference equations which is solved recursively.[1])

The total pool of active physicians, P(n), in any year n, is found by adding together each of the specialty groups, S_i. That is,

$$P(n) = \sum_{i=1}^{k} S_i(n)$$

where k = 54 and is the number of specialties and subspecialties recognized by and recorded in the AMA Physician Masterfile used in this project.

Changes which occur from one year to the next are all computed within specialty groups. Consider a particular group S (for the moment we drop the specialty index i since the discussion is confined to a single group). For year n, S(n) is a vector consisting of 49 elements, each element being the number of active specialists of a particular age. For instance,

$$S(1980) = (s1, s2, s3, \ldots s49) = (102, 153, 1800, \ldots 35)$$

where $s1$ = the number of 27-year-old (or younger) active physicians[2] in the given specialty at the end of 1980, here 102.

$s2$ = the number of 28-year-old active physicians in the given specialty at the end of 1980, here 153.

$s3$ = the number of 29-year-old active physicians in the given specialty at the end of 1980, here 1800.

.
.
.

$s49$ = the number of 75 year old (or older) active physicians in the given specialty at the end of 1980, here 35.

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[1] The 9th order is used because current information indicates that a significant number of residents enter practice over a period of nine years from graduation from medical school.

[2] Twenty-seven is assumed to be the age of the average medical school graduate based on AAMC's information on the average age of first-year medical school admissions (23.1).

The basic equation from which S(n) and therefore P (n) are calculated is the simple difference equation for population size:

$$S(n) = S(n-1) - L(n) + G(n) \qquad (1)$$

where S(n -1) = the pool at the end of the preceding year

L(n) = losses to the pool during the nth year

G(n) = gains to the pool during the nth year

Equation (1) superficially appears to be a first order difference equation, but it is not because the gain term, G(n), really depends on nine preceding years of GME output. This high-order dependence results from the fact that the input to active practice from a single year's medical graduates is distributed over nine years for some specialties. Thus, for example, of all physicians entering full active practice during 1980, a few will have graduated from medical school in 1979 and 1978, most in 1977 and 1976, some in 1974 and 1975, and so on back to 1971. (This description of additions to the active pool obviously means that we are not counting residents as fully active practitioners.)

Gains:

Gains for year n can be expressed in the following way

$$G(n) = R(n-1)f(1) + R(n-2)f(2) + \ldots + R(n-9)f(9) + C(n)$$

Where R(n-j) = the size of the jth year residency cohort in year (n-j)
f(j) = the fraction of those specialists entering practice in the nth year following graduation from medical school.
c(n) = physicians switching from other residencies to the one of interest here.

Note that C(n) has the same form as the additions from the parent residency. For example, some other residency program k will contribute

$$R_k(n-1)\ f(1) + R_k(n-2)\ f(2) + \ldots + R_k(n-9)\ f(9)$$

active physicians to the specialty we are considering, but now the Rs stand for the various residency cohort sizes of the kth residency program and the fs for the fractions migrating out of that residency program to the specialty of interest.

Therefore, the total size of the gain during the nth year to specialty i can be written as

$$G_i(n) = \sum_{j=1}^{9} \sum_{k=1}^{54} R_k(n-j)\ f_{ki}(j)$$

Where $f_{ki}(j)$ = the fraction going from residency k to specialty i in the jth year of GME

This equation is merely a shorthand way of expressing how many active practitioners are added to the specialty group i during year n from all residency programs and all medical school graduating classes of the preceding nine years.

G must be converted to vector form (that is, distributed by age) before it can be added to S in equation (1). This is done by using the age distribution of new practitioners, itself a vector A, i.e.

$$GA = (81, 82, 83, \ldots 849)$$

This formulation supposes that the gains are distributed in exact proportion to the number of new practitioners within each age group. Since the age spread of new practitioners is not great, the supposition seems reasonable.

Losses:

The form of the loss term, L(n), is much simpler. For physicians in a particular specialty,

$$L(n) = \sum_{a=1}^{49} s_a(n-1) \left[1 - (1-d_a)\,(1-r_a)\right]$$

where $s_a(n-1)$ = the number of active physicians of age a at the end of year (n-1).

d_a = probability of an active physician of age a (in the specialty of interest) dying during the year.

r_a = probability of an active physician of age a retiring or separating from practice during the year.[1]

In other words, L(n) is the sum of the losses due to death and retirement or separation from practice for each age group in the active pool of the preceding year.

These basic equations define a model that is both simple and flexible. All fundamental assumptions of physician supply are represented as input

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[1] In some cases, r_a is corrected for the probability of inactive physicians returning to a practice. This is especially true for females in the age groups 35-39 and 45-49.

variables -- R, f, d, r -- and can easily be altered to test sensitivities. Moreover, the forms of S, L, and G are structurally consistent with what is currently known about the underlying processes of GME and physician demography.

Actual calculation of the $S_i(n)$ values (i.e., the active specialty pools) requires a computer since each value includes thousands of steps. The computer program is described in a separate documentation submitted to the Office of Graduate Medical Education as part of this project.

4. DATA AND ASSUMPTIONS USED IN PROJECTING PHYSICIAN SUPPLY IN 1990

Baseline Supply

The Data Release Center of the American Medical Association prepared special frequency tables from the Physician Masterfile as of December 31, 1978 exclusively for use in this project. Excluding temporary aliens and physicians with unknown addresses, there were 428,195 M.D.'s in the U.S. in 1978. Of this number, almost 27,000 were classified as inactive; more than 80 percent of this group were 60 years or older and it was assumed that most will remain inactive. The temporary aliens, inactive physicians, and physicians with unknown addresses were excluded from the projection of physician supply in 1990. Therefore, the residual masterfile consisted of 401,364 M.D.s distributed as follows:

	Total	USMG	Percent of Total
Residents	60,610	48,460	80.0
Practitioners	315,201	246,443	78.2
Not Classified	25,553	15,879	62.1
Total	401,364	310,782	77.4

Information on the age, sex, and self-reported specialty distributions for each of the above classifications was used to project the number of physicians expected to remain in active practice in 1990.

As noted earlier, this study differentiates between physicians in training and in active practice for the purpose of estimating supply. Thus, the baseline supply, to which additions and subtractions will be made over the projection period, refers to the 340,754 practitioners and unclassified physicians. Although a substantial number of the unclassified physicians may still be in training, i.e., fellowships,[1] it was assumed that in 1990 all would have entered practice in the specialty reported in 1978. A detailed breakdown of the 1978 baseline data by specialty is shown later in Section Five in relation to the forecast of physician supply in 1990.

Additions to Baseline Supply

Over the projection period, physicians will enter practice after completing one or more years of graduate medical education. These physicians will come from 1) those who were in residency training as of December 31, 1978, and 2) those entering first year of graduate medical education from 1979 through 1989. The size of the first group is known, therefore only the

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[1] Almost two-thirds (15,840) of the unclassified physicians were under 35 years old; about 5,100 in this age group were in Internal Medicine and its subspecialties.

size of the second group has to be estimated. Since entrants to graduate medical education come from different sources, they are addressed separately.

1. Estimate of U.S. Medical School Graduates (USMG)

Graduates of U.S. medical schools starting in 1979 are estimated using known and projected first year enrollment and an assumed completion rate.

a. First Year U.S. Medical School Enrollment

The model uses actual first year U.S. medical school enrollments for 1975, 1976, 1977, and 1978 to estimate the number of USMGs added to the GME pool starting in 1979 (see Appendix A).[1] The enrollment for the 1978-1979 academic year was used to project future enrollments at the rate of 2 1/2 percent increase per year for a total increase of 10 percent over the 1978-1979 enrollment. This projection of FYEs from 1979-80 through 1983 is one percent less than AMA's projection for the same period.[2]

b. Rate of Completion

The model currently assumes that 95 percent of each FYE cohort will complete medical school in four years and will take an allopathic residency. This assumption is based on an analysis of the trends in first year enrollments and graduates in the past 13 years. The number of graduates is expressed as a percent of the FYE cohort, four years earlier, as shown below:

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1 Enrollment figures for 1978-79 published in the AAMC 1980-81 Admissions Book were used in the model. The total of 16,501 FYE reported in that source differs from the newly published AMA figure of 16,620 which includes 20 students enrolled at Oral Roberts University. The difference is due to the timing of data collection.

2 See Table 7, p. 852 of Medical Education Supplement JAMA, March 7, 1980.

MEDICAL SCHOOL GRADUATES EXPRESSED AS
PERCENT OF FIRST YEAR ENROLLMENT (FYE) COHORT

FYE Year/Grad Year	Percent
63/67	88
64/68	90
65/69	92
66/70	93
67/71	95
68/72	97
69/73	100
70/74	102
71/75	103
72/76	99
73/77	96
74/78	96

Note that in the early 70's the effects (presumably) of COTRANS and accelerated programs caused the number of graduates to exceed the FYE cohort. The model's current assumption of 95 percent of FYEs entering GME assumes no further COTRANS effect.[1] This assumption does not appear inconsistent with the student attrition observed in medical schools in 1978-79. The attrition shows two percent leaving after the first year, one and a half percent in the intermediate years and another half percent in the final year. If these figures were applied to each first year cohort, 96 out of every 100 first year students can be expected to graduate. However, since the attrition figures were based on total enrollment -- which reflects repeaters, transfers from foreign medical schools, and students entering medical schools with advanced standing -- the assumption of 95 percent completion rate used in the model appears reasonable.

2. Estimate of Foreign Medical Graduates (FMG)

FMGs in this model include both U.S. citizen and non-citizen FMGs. The basis for estimation of the future influx of FMGs into the M.D. GME pathway comes from an analysis of information provided to JWK International by the Executive Director of Educational Commission for Foreign Medical Graduates (ECFMG).

[1] COTRANS will no longer be in effect during the projection period, but other transfer mechanisms and Fifth Pathway will be treated as separate inputs to the model.

Foreign medical graduates, both alien and U.S. citizens, are required to hold ECFMG certification to be eligible for training in accredited GME programs. One of the conditions for ECFMG certification is passing any one of the following examinations: Visa Qualifying Examination (VQE), Federation Licensing Examination (FLEX)[1], or ECFMG examination. Only 20-30 individuals per year take the FLEX examination, and for purposes of this projection, only individuals passing VQE and ECFMG examinations have significant impact.

The VQE was instituted under the provisions of PL 94-484. Successful VQE examinees are eligible for immigrant visas. However, U.S. citizen FMG's, graduates of Canadian medical schools, physicians of national or international renown, and a substantial number of alien physicians, are exempt from the examination. Exempted alien physicians include:

a. close relatives (children, parents, spouses) of U.S. citizens or lawfully admitted aliens,

b. lawfully admitted refugees,

c. physicians who were in the U.S. prior to the effective date of PL 94-484, and held a visa other than a temporary visa,

d. Board certified M.D.'s who held a state license on or before January 9, 1977 and were in practice in a state on January 9, 1977.

Those FMGs, including U.S. citizens, exempted for the VQE must take the ECFMG examinations. Successful ECFMG examinees include individuals eligible for the exchange visitor program (temporary aliens) and fifth pathway participants, as well as all other U.S. citizen FMGs. Thus the number of successful VQE and ECFMG examinees represents the pool of FMGs entering GME residencies. Exhibit 7 shows the actual number of FMGs passing VQE and ECFMG examinations from 1977 to 1979. Over the projection period, it is estimated that the pool of successful examinees will average about 5,750 per year (see Exhibit 8). Of this number, it is estimated that 1,500 are U.S. citizens, 1,100 are successful VQE examinees who will likely practice in the U.S., and another 500 are VQE-exempt aliens with immigrant status. Thus, an estimated 3100 FMGs will be added annually to the GME pool, about 50 percent of them U.S. citizens. This was considered a conservative estimate, and GMENAC suggested that the estimate be modified to reflect an expected influx of U.S. citizen FMGs at the rate of 1500 in 1979 increasing to 2500 in 1983 and then leveling off.

3. Transfers from Other Programs

In the early and mid 70's, U.S. citizens enrolled in foreign medical schools tranferred to U.S. medical schools by different routes. One was the

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1 Established in 1967 to provide a uniform test for use by state medical boards for individuals (U.S.- born or foreign-born) who are not eligible to take the examinations of the National Board of Medical Examiners (NBME).

EXHIBIT 7

ACTUAL NUMBER OF PHYSICIANS PASSING VQE AND ECFMG EXAMINATIONS

	VQE*	ECFMG
1977		
Total	1163	5238
U.S. Citizens		912
1978		
Total	945	3364
U.S. Citizens		1020
1979		
Total	1448	4027
U.S. Citizens		1241

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* Under the current assumption not all successful VQE examinees will become permanent practitioners in the U.S.

EXHIBIT 8

PROJECTION OF THE NUMBER OF PHYSICIANS PASSING VQE AND ECFMG EXAMINATIONS

	VQE*	ECFMG
1980		
Total	1500	4117
U.S. Citizens		1360
1981		
Total	1575	4140
U.S. Citizens		1440
1982		
Total	1635	4163
U.S. Citizens		1520
1983		
Total	1710	4186
U.S. Citizens		1580
1984		
Total	1800	4209
U.S. Citizens		1660

* Under the current assumption not all successful VQE examinees will become permanent practitioners in the U.S.

Coordinated Transfer Program (COTRANS) of the Association of American Medical Colleges.[1] Another was the fifth pathway clerkship where U.S. students complete their medical degrees abroad and return to the U.S. for a year of clinical training under the sponsorship of a U.S. medical school. Since fifth pathway participants must be certified by ECFMG, their effect on the size of the medical education pool was reflected in the estimate of USFMG entrants (See preceding discussion).

The number of transferees to U.S. medical schools in the past years is summarized below.[2]

Advanced Placement Students from Foreign Medical Schools

	Total Advanced Placement Foreign Medical Schools	COTRANS Students
1976-77	494[1]	373[2]
1977-78	401[1]	201[2]
1978-79	858[1]	644[2]
1979-80	318[3]	[4]

1) J.A.M.A., 243:055, March 7, 1980.

2) Division of Student Studies, AAMC.

3) Based on incomplete data from the Division of Student Services, AAMC. Thirty-five more advanced placement students are expected from seven medical schools.

4) Information not available, however for the 1979 academic year all students eligible for the COTRANS program were required to apply through COTRANS.

A small number of graduates of osteopathic schools elect allopathic residencies. Over the past 10 years, an average of a 100 per year participated in the National Residents Matching Program.[3]

These transfers from foreign medical schools and programs not accounted for in the earlier estimates of U.S. and foreign medical school graduates are assumed to expand the GME pool by a total of 500 entrants per year for the duration of the projection period.

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[1] This program has been discontinued and is replaced by the Medical Sciences Knowledge Profile (MSKP) admissions.

[2] AAMC personal communication to the Office of Graduate Medical Education, HRA.

[3] NRMP Directory - October, 1980, pre publication copy.

4. Summary of Annual Expansion of the GME Pool

From the preceding assumptions on growth on first year enrollment, completion rate, FMG influx and other transfers, input to the GME pool over the projection period can be summarized as follows:

	USMGs	FMGs	Transfers	Total
1979	14583	3100	500	18183
1980	14884	3350	500	18734
1981	15327	3600	500	19427
1982	15676	3850	500	20026
1983	16067	4100	500	20667
1984	16459	4100	500	21059
1985	16850	4100	500	21450
1986	17242	4100	500	21842
1987	17242	4100	500	21842
1988	17242	4100	500	21842
1989	17242	4100	500	21842
1990	17242	4100	500	21842
Total	196056	46700	6000	248756

Not all of this input will be in active practice in 1990. The rate at which these residents are added to the active practice pool depends on their residency choices. This is discussed in the following section.

5. Residency Selection

Selection of residency programs by medical graduates determines to a large extent the number of practitioners in different specialties. Most recently published AMA data show the number of residents in their first year of training in the given specialty and not numbers of trainees in their first year of graduate medical education (G-1).[1] The model requires the number of trainees in G-1 positions in order to project the GME output into practice at various years following medical school graduation. Therefore, the NRMP data on the fraction of medical graduates entering residency programs were used to distribute graduates into G-1 positions.[2] As discussed earlier, the G-1 distribution was further adjusted using conversion factors derived from the NRMP tracking study (See Exhibit 2, p. 7). The adjustment is made to correct for the contribution of flexible residencies and other interspecialty shifts occurring at the G-2 level. The 1979 distribution was held constant for future graduates.

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1 Graduate Medical Education in the U.S., Medical Education Supplement, JAMA, 243: 867, March 7, 1980.

2 Table II-1, NRMP Directory, October, 1980, prepublication copy.

Separate distributions were calculated for USMGs, FMGs, and Transfers. These are displayed in Exhibit 9.

6. GME Output into Active Practice

The basis for estimating the probability of residents entering practice after spending some time in graduate medical education was discussed in Section Four. Detailed GME output probabilities were developed for each of 19 parent specialties selected by residents in the first year of graduate medical education. These probabilities are summarized in Exhibit 10; the summary does not show the complex interspecialty shifts which the model employs, but is displayed only to show that the rate of entry into practice differs among programs.[1] The actual number of residents entering practice annually is a function of the fraction of residents entering each residency program in a given year and the output probabilities summarized in Exhibit 10. Based on the pattern of first-year residency selection of USMGs in 1979, which is held constant for the duration of the projection period, an estimate of the yearly output of residents into practice is shown in Exhibit 11. The output is expressed in relation to the year of graduate medical education, for example, the Exhibit shows that 44 percent of all USMG residents entering graduate medical education in 1979 will have entered practice by 1982. Read in another way, the Exhibit says that over the projection period, the model assumes that 9 percent of a residency cohort will enter practice after one year in GME, another 6 percent will do so after two years, and so on. It takes approximately 9 years to get 100 percent of a residency cohort into active practice. Based on the assumption that the residency selection in 1979 will continue, an estimate of the percentage of entry of USMGs into practice in different specialties as employed in the current projection is shown in Exhibit 12. The yearly output into practice as well as the distribution into practice specialties will change if the pattern of residency selection, the length of residency programs, or the interspecialty shifts during training changes significantly from historical trends. Similarly, rates of output into practice for FMGs differ from those of the USMGs due to differences in residency choices.

Separation Rates

Projection of the number of physicians in active practice in 1990 also requires the estimate of the number of physicians retiring or dying within the projection period. For this estimate, separation rates developed by the Division of Health Professions Analysis for its SOAR program were used. The separation rates included retirement from medicine (based on

[1] Detailed probability matrices used in the model are included in a separate computer program documentation.

EXHIBIT 9

ADJUSTED FIRST YEAR RESIDENCY DISTRIBUTION 1979

Residency Program	USMG	Transfers NAG	FMG
1. Family Practice	.1384	.1288	.0691
2. Internal Medicine	.3223	.3375	.3472
3. Pediatrics	.1012	.0820	.1549
4. Obstetrics	.0707	.0935	.0816
5. Dermatology	.0080	.0097	.0083
6. Neurology	.0104	.0116	.0186
7. Ophthalmology	.0256	.0258	.0276
8. Psychiatry	.0456	.0518	.0373
9. General Surgery	.1075	.1200	.1164
10. Neurosurgery	.0063	.0092	.0057
11. Orthopedics	.0356	.0321	.0219
12. Otolaryngology	.0089	.0076	.0076
13. Urology	.0054	.0055	.0032
14. Anesthesiology	.0274	.0264	.0259
15. Pathology	.0284	.0137	.0296
16. Physical Medicine	.0022	.0044	.0021
17. Diagnostic Radiology	.0409	.0290	.0307
18. Therapeutic Radiology	.0015		.0027
Totals*	.9863	.9886	.9904

* Total does not sum to 1.000 due to rounding and to about 1% of residents going into other specialties at the G-2 level.

EXHIBIT 10

PROBABILITY OF RESIDENTS ENTERING PRACTICE BY PROGRAM AND YEAR OF GRADUATE MEDICAL EDUCATION[1]

Residency Program	Year of Graduate Medical Education									Total
	1	2	3	4	5	6	7	8	9	
AN		.014	.082	.463	.414	.019	.008			1.00
D				.100	.500	.300	.100			1.00
DR			.008	.169	.538	.177	.108			1.00
GP		.606	.056	.251	.057	.022	.006	.002		1.00
GS		.029	.001	.071	.111	.376	.271	.113	.028	1.00
IM			.076	.340	.181	.197	.154	.051	.001	1.00
N		.008	.043	.188	.676	.067	.017	.001		1.00
NS				.100	.600	.200	.100			1.00
OBG		.007	.063	.288	.576	.056	.010			1.00
OPH		.002	.040	.154	.638	.145	.021			1.00
ORS		.011	.050	.109	.221	.546	.048	.015		1.00
OTO		.005	.038	.103	.104	.096	.549	.086	.019	1.00
P		.013	.077	.469	.303	.103	.023	.012		1.00
PD		.008	.105	.533	.214	.101	.036	.003		1.00
PM			.100	.500	.400					1.00
PTH		.015	.065	.152	.529	.089	.131	.019		1.00
R		.008	.034	.155	.562	.181	.040	.020		1.00
TR			.008	.169	.538	.177	.108			1.00
UR		.007	.044	.037	.062	.571	.217	.052	.010	1.00

[1] Practice specialty may be different from initial residency program.

EXHIBIT 11

ESTIMATE OF YEARLY OUTPUT OF RESIDENTS INTO PRACTICE BASED ON 1979 USMG RESIDENCY SELECTION

Year of GME	Percent of GME-1 Cohort	Cumulative Percent of GME-1 Cohort
1st	0.0	0.0
2nd	9.1	9.1
3rd	6.0	15.1
4th	29.0	44.1
5th	25.0	69.1
6th	17.0	86.1
7th	10.2	96.3
8th	3.3	99.6
9th and after	0.4	100.00

EXHIBIT 12

ESTIMATE OF
TOTAL RESIDENCY OUTPUT INTO SPECIALTY PRACTICE

Specialty	Percent of 1979 USMG Residency Input[1]
Anesthesiology	3.1
Dermatology	1.6
General Practice	13.4
Internal Medicine	13.3
Internal Medicine Subspecialties	15.1
Neurology	1.8
Obstetrics - Gynecology	7.1
Ophthalmology	3.2
Psychiatry	4.8
Child Psychiatry	0.8
Pediatrics	7.2
Pediatric Specialties excluding Child Psychiatry	1.3
Physical Medicine	0.3
Pathology	2.9
Radiology/Diagnostic Radiology	5.4
Therapeutic Radiology	0.5
General Surgery	4.5
Surgical Specialties	11.5
Other Specialties	2.2
Total	100.00

[1] Assumes residency selection pattern of USMGs in 1979, and interspecialty shifts occurring as in the past decade.

cross-sectional analysis of retirement data on AMA physicians for 1967) and mortality rates (based on Goodman's Study of Mortality of Physicians)[1] for each sex and 5-year age group. The combined mortality and retirement rates are as shown in Exhibit 13.

Separation rates were applied to each specialty since each specialty has a different age and sex distribution. Additions to the pool were aged based on an average age of 23 years reported by AAMC for first year medical school admissions in 1977.

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[1] As reported in Hendrickson, R.A., "Specialists Outlive Generalists," Prism, December, 1975.

EXHIBIT 13

ANNUAL SEPARATION RATES FOR PHYSICIANS*

Age	Percent	
	Male	Female
<30	.096	.430
30-34	.120	1.330
35-39	.148	- .102**
40-44	.238	1.310
45-49	.477	- .251**
50-54	.801	1.207
55-59	1.416	2.013
60-64	3.115	3.249
65-69	6.597	4.797
70-74	11.385	11.537
75+	19.165	18.195

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* Source: SOAR Program Run, Division of Health Professions Analysis, 3/18/80.

** Indicates return from inactive status is greater than separation rate.

5. FORECAST OF PHYSICIAN SUPPLY IN 1990

Preceding discussions dealt with the basis and methodology for estimating the supply of practicing allopathic physicians in 1990. Although the methodology can be adapted to estimate the supply of osteopathic physicians, insufficient information on osteopathic residency experience currently prohibits projection of the number of D.O.'s through the use of the model. However, the American Osteopathic Association (AOA) Task Force on Graduate Education has estimated the number of D.O.'s for 1988-1989 and its estimate is used in this report. This estimate (29,094) is adjusted downward to account for residents and interns; in 1978, residents and interns represented 9 percent of active D.O.'s. AOA's projection is based on an expected increase in student enrollment in the next 10 years, from 4,225 in 1978 to 7,152 in 1989. The number of specialists in 1990 is difficult to estimate in view of the lack of information on expansion of specialty residencies. For purposes of this report the distribution of specialists reported in 1978 was maintained in the 1990 projection.

The estimate of the supply of practicing physicians in 1990 is compared with the supply in 1978 in Exhibit 14.[1] The 1990 estimates are broken down by specialty, type of physician (M.D. or D.O.), and school of graduation. The residual of the 1978 M.D. base is added to the USMG contribution to the supply in 1990 and is further disaggregated in Exhibit 15. The two Exhibits show that deaths and retirement are estimated to reduce the 340,754 active M.D.s in 1978 by about 20 percent in 1990, (down to 274,572, see first two columns of Exhibit 15). Over the projection period, about 169,000 USMGs will be added to the pool of active practitioners in 1990, with an assumed growth of first-year enrollment at an annual rate of 2 1/2 percent through 1983. Because of the lag time between first-year enrollment in medical school and active practice of medicine, the full effect of the increase in enrollment is not seen in 1990, but sometime after 1995. On the other hand, expanding the GME pool by 3000-4000 per year starting in 1979 adds more than 30,000 physicians to the supply in 1990, which is about 15 percent of total additions. The implication here is that in the immediate future, changes in first-year medical school enrollments have relatively less effect than changes in first-year residency positions.

Under the assumptions discussed in the preceding sections, the estimated supply in 1990 represents a 40 percent increase in practitioners over the 1978 base, after adjustments for deaths and separations from practice. This appears consistent with the observed growth in physician supply in the past decade (See Exhibit 16).

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[1] Note that although the baseline in 1978 excluded interns and residents, it may have included physicians in fellowship training.

Exhibit 14
ESTIMATE OF 1990 SUPPLY OF PHYSICIANS
COMPARED TO 1978 SUPPLY
(Excludes Residents and Interns)

Specialty Area	1978 Baseline #			1990 Estimates				
				Base M.D.	MD ADDITIONS			
	MD	DO	Total	+ USMG	FMG	OTHER	DO's	Total
1. CHILD MEDICAL CARE								
General Pediatrics (PD)	21,828	95	21,923	31,252	3,610	259	158	35,279
Pediatric Endocrinology (PDE)	—	—	—	186	48	3	—	237
Pediatric Cardiology (PDC)	594	—	594	798	70	5	—	873
Pediatric Hemotology/Oncology (PHO)	—	—	—	388	99	7		494
Pediatric Allergy (PDA)	447	—	447	685	82	6	—	773
Pediatric Nephrology (PNP)	—	—	—	152	39	3	—	194
Neonatal (NPM)	—	—	—	538	136	10	—	684
Pediatric Neurology (PNR)	—	—	—	286	73	5	—	364
2. PSYCHIATRY								
Adult Care Psychiatry (P)	23,730	96$	23,826$	27,501	1,380	224	158$	29,263$
Child Care Psychiatry (CHP)	2,848	—	2,848	3,813	205	30	—	4,048
3. DERMATOLOGY (D)	4,693	32	4,725	6,477	521	75	54	7,127
4. OBSTETRICS/GYNECOLOGY (OBG)	21,443	103	21,546	29,266	2,519	380	170	32,295
5. ADULT MEDICAL CARE								
General Internal Medicine (IM)	42,062	303	42,365	58,268	4,889	613	505	64,275
Allergy & Immunology (A, AI, IG)	2,076	—	2,076	2,724	243	30	—	2,997
Cardiology (CD)	8,654	—	8,654	13,073	1,030	134	—	14,237
Endocrinology (END)	1,661	—	1,661	3,339	317	41	—	3,697
Gastroenterology (GE)	3,374	—	3,374	5,938	522	66	—	6,526
Hematology (HEM)	1,934	—	1,934	2,365	109	14	—	2,488
Oncology (ON)	1,094	—	1,094	4,191	544	71	—	4,806
Neoplastic Diseases (ND)	636	—	636	541	0	0	—	541
Pulmonary Diseases (PUD)	3,138	—	3,318	5,930	580	75	—	6,585
Rheumatology (RHU)	1,250	—	1,250	2,552	254	33	—	2,839
Diabetes (DIA)	270	—	270	192	0	0	—	192
Geriatrics (GER)	519	—	519	1,676	200	42	—	1,918
Nutrition (NTR)	115	—	115	123	10	1	—	134
Nephrology (NEP)	1,864	—	1,864	4,134	408	53	—	4,595
Infectious Disease (ID)	1,121	—	1,121	2,729	290	38	—	3,057
6. FAMILY PRACTICE (GP/FP)	52,279	13,048	65,327	58,059	3,039	651	23,033	84,782
7. GENERAL SURGERY (GS)	26,944	276	27,229	29,411	1,273	177	460	31,321
Colon & Rectal Surgery (CRS)	674	55	729	644	31	4	93	772
8. NEUROSURGERY (NS)	2,787	9	2,786	4,448	328	56	15	4,847

Exhibit 14 (continued)
ESTIMATE OF 1990 SUPPLY OF PHYSICIANS
COMPARED TO 1978 SUPPLY
(Excludes Residents and Interns)

Specialty Area	1978 Baseline #			1990 Estimates				
				Base M.D.	MD ADDITIONS			
	MD	DO	Total	USMG	FMG	OTHER	DO's	Total
9. ORTHOPEDIC SURGERY (ORS)	11,367	99	11,466	17,679	997	171	164	19,011
10. OTOLARYNGOLOGY (OTO)	2,454	134*	5,738*	7,318	424	58	221*	8,021*
11. PLASTIC SURGERY (PS)	2,454	—	2,454	3,470	184	26	—	3,680
12. THORACIC SURGERY (TS)	1,995	15	2,010	2,560	123	17	24	2,724
13. UROLOGY (U)	6,685	32	6,717	8,338	386	60	—	8,784
14. OPHTHALMOLOGY (OPH)	11,077	134*	11,211	14,026	1,022	127	221*	15,396*
15. EMERGENCY MEDICINE**	—	—	—	—	—	—	—	
16. PREVENTIVE MEDICINE (GPM)	732	—	732	740	57	6	—	803
Public Health (PH)	2,351	—	2,351	2,253	174	21	—	2,448
17. PHYSIATRICS (PM)	1,795	52	1,848	2,107	112	25	87	2,331
18. NEUROLOGY (N)	4,329	96$	4,425$	7,004	720	68	158$	7,950$
19. ANESTHESIOLOGY (AN)	13,801	194	13,995	17,286	995	133	323	18,737
20. PATHOLOGY (PTH)	11,377	93	11,470	14,757	863	61	156	15,837
Forensic Pathology (FOP)	233	—	233	173	0	0	—	173
21. RADIOLOGY (R)	10,992	328	11,320	12,851	512	64	544	13,971
Diagnostic Radiology (DR)	4,794	—	4,794	9,891	800	100	—	10,791
Therapeutic Radiology (TR)	1,286	—	1,286	1,600	96	5	—	1,701
22. NUCLEAR MEDICINE (NM)	—	62	62	19	4	0	107	130
23. OCCUPATIONAL MEDICINE (OM)	2,348	—	2,348	1,494	32	4	—	1,530
AEROSPACE MEDICINE (AM)	581	—	581	702	38	6	—	746
24. OTHER SPECIALTIES (OS)	10,274	70	10,344	10,004	0	0	144	10,148
25. UNSPECIFIED (US)	8,652	—	8,652	7,934	0	0	54	7,988
TOTALS	340,754	15,096	355,850	443,845	30,388	4,058	26,470	504,761

- Sources: 1978 AMA Masterfile, 1979 AOA survey.
$ - Psychiatry and Neurology are combined specialties for DOs; number included in total only once.
* - Ophthalmology and Otolaryngology are combined specialties for DOs; number included in total only once.
** - Included in Other Specialties (OS).

Exhibit 15
Residual 1978 AMA Physician Masterfile and
Estimate of USMG Additions to Supply in 1990*

	Specialty	Residual 1978 Base**	USMG			Totals 1990
			Residual 1978 Base	Additions	Total	
1.	CHILD MEDICAL CARE					
	General Pediatrics (PD)	7,185	11,825	12,242	24,067	31,252
	Pediatric Endocrinology (PDE)	0	0	186	186	186
	Pediatric Cardiology (PDC)	193	335	270	605	798
	Pediatric Hematology/ Oncology (PHO)	0	0	388	388	388
	Pediatric Allergy (PDA)	84	281	320	601	685
	Pediatric Nephrology (PNP)	0	0	152	152	152
	Neonatal (NPM)	0	0	538	538	538
	Pediatric Neurology (PNR)	0	0	286	286	286
2.	PSYCHIATRY					
	Adult Care Psychiatry (P)	6,830	12,433	8,238	20,671	27,501
	Child Care Psychiatry (CHP)	780	1,712	1,321	3,033	3,813
3.	DERMATOLOGY (D)	571	3,092	2,814	5,906	6,477
4.	OBSTETRICS/GYNECOLOGY (OBG)	5,750	11,761	11,715	23,476	29,226
5.	ADULT MEDICAL CARE					
	General Internal Medicine (IM)	13,649	21,887	22,732	44,619	58,268
	Allergy & Immunology (A, AI, IG)	279	1,179	1,266	2,445	2,724
	Cardiology (CD)	1,908	5,078	6,087	11,165	13,073
	Endocrinology (END)	362	1,115	1,862	2,977	3,339
	Gastroenterology (GE)	678	2,243	3,017	5,260	5,938
	Hematology (HEM)	459	1,268	638	1,906	2,365
	Oncology (ON)	268	731	3,192	3,923	4,191
	Neoplastic Disease (ND)	95	446	0	446	541
	Pulmonary Disease (PUD)	692	1,838	3,400	5,238	5,930
	Rheumatology (RHU)	173	889	1,490	2,379	2,552
	Diabetes (DIA)	38	154	0	154	192
	Geriatrics (GER)	84	166	1,426	1,592	1,676
	Nutrition (NTR)	18	59	46	105	123
	Nephrology (NEP)	537	1,203	2,394	3,597	4,134
	Infectious Disease (ID)	166	861	1,702	2,563	2,729
6.	FAMILY PRACTICE (GP/FP)	8,542	26,523	22,994	49,517	58,059
7.	GENERAL SURGERY (GS)	8,332	13,545	7,534	21,079	29,411
	Colon & Rectal Surgery (CRS)	123	291	230	521	644
8.	NEUROSURGERY (NS)	695	1,688	2,065	3,753	4,448

Exhibit 15
(continued)

Specialty	Residual 1978 Base**	USMG			Totals 1990
		Residual 1978 Base	Additions	Total	
9. ORTHOPEDIC SURGERY (ORS)	2,065	7,452	8,162	15,614	17,679
10. OTOLARYNGOLOGY (OTO)	1,057	3,305	2,956	6,261	7,318
11. PLASTIC SURGERY (PS)	568	1,547	1,355	2,902	3,470
12. THORACIC SURGERY (TS)	579	1,068	913	1,981	2,560
13. UROLOGY (U)	1,570	3,954	2,814	6,768	8,338
14. OPHTHALMOLOGY (OPH)	1,485	7,002	5,539	12,541	14,026
15. EMERGENCY MEDICINE***					
16. PREVENTIVE MEDICINE (GPM)	107	409	224	633	740
Public Health (PH)	230	1,234	789	2,023	2,253
17. PHYSIATRICS (PM)	865	652	590	1,242	2,107
18. NEUROLOGY (N)	1,399	2,575	3,030	5,605	7,004
19. ANESTHESIOLOGY (AN)	6,000	5,995	5,291	11,286	17,286
20. PATHOLOGY (PTH)	4,470	5,511	4,776	10,287	14,757
Forensic Pathology (FOP)	64	109	0	109	173
21. RADIOLOGY (R)	2,726	6,553	3,572	10,125	12,851
Diagnostic Radiology (DR)	1,160	3,160	5,571	8,731	9,891
Therapeutic Radiology (TR)	481	688	431	1,119	1,600
22. NUCLEAR MEDICINE (NM)	0	0	19	19	19
23. OCCUPATIONAL MEDICINE (OM)	184	1,169	141	1,310	1,494
AEROSPACE MEDICINE (AM)	77	389	236	625	702
24. OTHER SPECIALTIES (OS)	1,760	5,925	2,319	8,244	10,004
25. UNSPECIFIED (US)	5,677	2,257	0	2,257	7,934
TOTALS	91,015	183,557	169,273	350,511	443,845

* Excludes residents and interns. This table is the breakdown of the 1990 M.D. Base + USMG column in Exhibit 14 .
** Includes FMGs, CMGs and unclassified USMG in 1978 AMA file.
*** Included in other specialties.

EXHIBIT 16

SUPPLY OF ALLOPATHIC PHYSICIANS
1970-1978

Year	Active Physicians		Subtotal Active	Interns and Residents	Total Supply
	Classified	Not Classified			
1970	259,617	358	259,975	51,228	311,203
1971	265,859	3,529	269,388	52,840	322,228
1972	267,352	12,356	279,708	53,551	333,259
1973	266,115	13,744	279,859	58,252	338,111
1974	271,244	20,343	291,587	59,022	350,609
1975	282,478	26,145	308,623	57,802	366,425
1976	285,397	30,129	315,526	63,046	378,572
1977	301,114	18,350	319,464	62,505	381,969
1978	315,201	25,553	340,754	60,610	401,364

Data Source: Physician Distribution and Medical Licensure in the U.S. Center for Health Services Research and Development, American Medical Association 1970-1978.

6. SUMMARY AND CONCLUSIONS

The model described here is constrained only by the limits and reliability of data and assumptions used in estimations. The best data available were provided by responsible agencies. The assumptions were developed from observed trends in medical education in the past decade and envisioned changes in the next. The assumptions were further confirmed by experts in medical education.

The strength of the model lies in its conceptualization as a system that captures the flow of individuals through the continuum of medical education -- both undergraduate and graduate. Thus it produces supply estimates that are probably closer to reality than previous estimates. A comparison between the model developed in this project (IPSM) and the model used by the Division of Health Professions analysis (SOAR) is shown in Exhibit 17. The critical difference between the models lies in the design concept and definitions used. In view of this, the SOAR model is expected to overstate supply to the extent that it considers medical graduates as full-time equivalent practitioners. With regard to specialty distribution, the IPSM is the more reliable model since it considers interspecialty shifts for a nine-year period for each residency cohort. This does not imply, however, that IPSM has predicted the supply of physicians with 100 percent precision. Indeed, a substantial work needs to be done, not so much in the development of the model, but in the development of data and assumptions upon which the model operates. The model, as it exists, can accept input at the lowest level of detail, i.e., at the level of ethnic distribution on a school-by-school basis. If, in fact, more extensive and accurate data are available on rates of completion of medical education, residency selection, interspecialty shifts, and separation rates by sex and ethnic group, then supply modeling can be made more precise. Some of the information can be generated through ongoing data collection efforts by the same agencies that provided materials for this project. Especially important is the residency selection and training of residents since this information is crucial to the operation of model. The current version of the model employs specialty transition probabilities developed from an analysis of physician practice and residency data on medical school graduates from 1961 to 1975. Although the probabilities appeared stable over the period studied, they had not reflected the:

- Full impact of federal support of family practice programs
- Total phase-out of internships
- Emergence of new specialties such as emergency medicine.

It will be essential to compare results of ongoing or future tracking studies of residents with the transition probabilities used in this project to determine if the above changes in graduate medical education have affected interspecialty shifts observed in the past two decades.

Further, interspecialty shifts after physicians enter practice have to be studied more fully. The current version of the model has not fully captured

EXHIBIT 17

COMPARISON OF SOAR AND IPSM
PROJECTION METHODOLOGY FOR ALLOPATHIC PHYSICIANS

Concepts and Definitions of Physician Supply

SOAR:

- All U.S. medical graduates, Canadian, and foreign medical graduates entering the U.S. plus active supply in the base year (1974) adjusted for deaths, retirement, and emigration (of foreign graduates) over the projection period.
- Physicians in training are counted as full-time practitioners.

IPSM:

- Time lagged output of graduate medical education programs into practice over the projection period plus active practitioners in the base year (1978) adjusted for deaths and retirement over the projection period.
- Residents and fellows in training are counted as one-third full-time physician equivalent.

Computational Procedures

SOAR:

- Two distinct estimation calculations: 1) to determine aggregate supply and 2) to project distribution of supply among medical specialties.

IPSM:

- A series of continuous computations to determine number of active practitioners in each specialty and to sum over all specialties to obtain aggregate supply.

Data Input and Assumptions

Baseline Supply

SOAR:

- 1974 AMA masterfile active supply.

IPSM:

- 1978 AMA masterfile selected data specified for model input.

First Year Enrollment

SOAR:

- Historical data through 1977; base of 16,136 in 1977 projected to 18,047 (basic estimate) in 1987. Based on projected growth in federal capitation, federal construction grants, new schools, and potential state and local support of new schools.

IPSM:

- Historical data through 1978; base of 16,501 in 1978 projected to 18,151 in 1982 and constant thereafter based on an assumed annual growth of 2 1/2 percent per year for 4 years starting in 1979.

EXHIBIT 17 (continued)

Completion Rates

SOAR:

- Series of attrition rates: 5.4 percent in 1976 to 7.5 percent in 1987.
- Actual input data in computer program reads a range of 96 to 93 percent for males and 94 to 91 percent completion rates for females.

IPSM:

- 95 percent completion rates held constant over the projection period and applied to both males and females.

FMGs

SOAR:

- Does not include U.S. citizens. Size of entrants derived from estimates of passers of Visa Qualifying Examination (VQE) and temporary visas.
- Total new entry supply projected from 7,316 annually in 1975 decreasing to 3,023 in 1990 (basic estimate).

IPSM:

- Includes U.S. citizen graduates of foreign medical schools; projections based on trends in ECFMG certifications.
- Total new entry supply estimated annually at 3,100 in 1979 increasing to 4,100 in 1983, then constant thereafter.

Transfers from Other Schools

SOAR:

- 209 per year held constant through 1988.

IPSM:

- 500 per year held constant from 1979 through 1990.

First Year Residency Distribution

SOAR:

- Based on filled first residency positions in AMA/LCGME Directory of Approved Residencies.
- Distribution adjusted for duplication in primary/subspecialty residencies--adjustment made for internal medicine, pediatrics, general surgery, psychiatry, and pathology.
- Regression analysis of 6 years trends (1968, 70-74, and 76) to project distribution through 1980.

IPSM:

- Historical data reported by National Resident Matching Program

EXHIBIT 17 (continued)

(NRMP) on residency selection of U.S. and foreign medical graduates were used.

- Selection pattern in 1979 was held constant for the rest of the projection period.
- Distribution at first graduate year (G-1) level adjusted for interspecialty shifts at (G-2) level using NRMP tracking data.

Graduate Medical Education Process

SOAR:

- Not included in model.

IPSM:

- Crux of the model; determines output into practice by age, sex, and specialty.

Specialty Distribution

SOAR:

- 28 specialties plus a "miscellaneous" category; "unclassified" was distributed according to first year residency distribution.
- Estimates of future supply in each specialty are a function of the projected trend of growth in adjusted first-year residency distribution in each specialty, with further adjustments in some specialties so that the sum of distributions equals 100 percent.[1] The aggregate supply is then converted to specialty counts using the resulting specialty distribution.

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[1] Specialty shifts during residency and practice in the specialty projection are being considered for incorporation in the SOAR model. (See Appendix VI, prepublication copy of The Current and Future Supply of Physician Specialists, DHPA Report No. 79-13, July 1980).

These specialty shifts are being derived from Elzinga's GME model (Modeling the Graduate Medical Education System, Final Report, HRA Contract No. 231-77-0064, May 1979) and Holden and Levit's Study of Physician Specialty Migration (Holden, W.D., and Levit E.J., Migration of Physicians from One Specialty to Another, JAMA, 1979, 239:205-209). The methodology does not appear to be an improvement over the IPSM method for the following reasons: The data bases used in both Elzinga's and Holden's studies are subsets of the data bases used in developing transition probabilities incorporated in the IPSM projections. The Holden and Levit study, for example, analyzed specialty migration in 1971 and 1976 of about 2000 physicians who graduated from medical school in 1960, 1964 and 1968. Strictly speaking, this was not a tracking study but a snapshot of specialty change in two time periods for three different cohorts. Thus, it does not represent trends in transitions in GME or in practice.

In comparison, GME transition and output probabilities used in IPSM were developed from Hunt's analysis of about 40,000 physicians who graduated in 1961, 1963, 1965, 1967, 1969, 1971, 1973 and 1975 (See Hunt, Leon, op.cit., p. 6). The self-reported specialties of these physicians were tracked until designations were stablilized over the period of study -- 1961 to 1976. It took 15 years for some physicians to stabilize their specialty designations; in most cases, designations were stable within ten years from medical school graduation.

EXHIBIT 17 (continued)

IPSM:

- 52 specialties plus an "Other" and unspecified categories; "Unclassified" refers to activity (i.e., resident, practitioner, inactive) but is classified by specialty.
- Estimates of future supply in each specialty are a function of rate of entry into residency, interspecialty shifts, and probability of entering practice over a period of nine years from entry into the first year of graduate medical education.

Separation Rates

SOAR:

- Age and sex specific death and retirement rates for M.D. population plus emigration rate of FMGs.

IPSM:

- Death and retirement rates as used in SOAR: no emigration rate since temporary aliens are not included in base period or new FMG entrants.

specialty shifts during active practice in the smaller specialities such as therapeutic radiology, dermatology, etc. A more detailed coding and reporting of AMA self-designations of specialties is needed to conduct future studies in tracking specialty changes during practice.

Lacking the refinements suggested above, the Integrated Physician Supply Model developed in this project, nonetheless, represents an improved method of forecasting supply. With its adjunct computational procedures (Appendix B) and flexibility to accept input at different levels of aggregation, it is a useful tool in testing assumptions made to achieve a desired supply. It is, therefore, a valuable aid for decision-makers in weighing policy options and directions.

ADDENDUM

It should be noted that projected estimates included in this report do not include the projected number of residents in 1990. Resident projections by specialty were estimated using the assumptions contained in this report and are incorporated in the supply projections found in Volumes I and II of the GMENAC Report.*

Futhermore, severl of the specialty-specific supply estimates contained in this report may be undercounted because of inadequacies of the AMA data base. These limitations are described in the final GMENAC Reports.

Office of Graduate
Medical Education

*Graduate Medical Education National Advisory Committee (GMENAC). Summary Report. Vol. I of the GMENAC Report to the Secretary, Department of Health and Human Services, DHHS Pub. No. (HRA) 81-651, Hyattsville, Md., Nov. 1980.

____ Modeling, Research, and Data Technical Panel. Vol. II of the GMENAC Report to the Secretary, Department of Health and Human Services. DHHS Pub. No. (HRA) 81-652, Hyattsville, Md., Nov. 1980.

APPENDIX A

FIRST YEAR ENROLLMENT

1975-76 through 1978-79

U.S. MEDICAL SCHOOL FIRST-YEAR ENROLLMENT BY SEX

	First-Year Enrollment											
	75-76			76-77			77-78			78-79		
	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women
1. Alabama	147	115	32	168	136	32	169	131	38	169	136	33
2. Alabama, South	67	59	8	69	60	9	67	54	13	70	55	15
3. Albany	110	83	27	128	89	39	128	95	33	128	100	28
4. Albert Einstein	183	129	54	181	128	53	183	133	50	186	137	49
5. Arizona	99	61	38	93	69	24	92	65	27	88	66	22
6. Arkansas	123	93	30	123	102	21	138	114	24	138	104	34
7. Baylor	168	133	35	174	135	39	168	126	42	167	130	37
8. Boston University	139	98	41	141	88	53	140	87	53	141	104	37
9. Bowman Gray	101	79	22	109	92	17	111	90	21	107	91	16
10. Brown	62	43	19	60	36	24	60	42	18	62	44	18
11. California, U. of: Davis	102	73	29	103	58	45	103	76	27	102	68	34
12. " Irvine	78	64	14	75	60	15	82	61	21	106	74	32
13. " Los Angeles	148	109	39	148	113	35	146	108	38	145	106	39
14. " San Diego	96	84	12	97	77	20	97	72	25	129	101	28
15. " San Francisco	148	90	58	160	104	56	161	104	57	159	92	67
16. California, Southern	139	119	20	140	109	31	139	117	22	136	111	25
17. Case Western Reserve	145	102	43	145	99	46	143	93	50	147	105	42
18. Chicago Medical	125	90	35	115	87	28	116	88	28	120	87	33
19. Chicago-Pritzker	105	87	18	105	90	15	104	84	20	104	82	22
20. Cincinnati	194	150	44	200	139	61	197	141	56	199	150	49
21. Colorado	128	97	31	127	88	39	127	92	35	128	98	30
22. Columbia	150	99	51	150	95	55	148	101	47	150	112	38
23. Connecticut	80	56	24	80	58	22	81	57	24	83	59	24
24. Cornell	102	74	28	104	74	30	102	66	36	96	68	28
25. Creighton	110	98	12	110	89	21	113	93	20	109	92	17
26. Dartmouth	68	51	17	65	49	16	66	43	23	67	46	21
27. Duke	119	83	36	121	88	33	119	82	37	120	83	37
28. East Carolina	-	-	-	-	-	-	28	22	6	37	30	7
29. Emory	112	81	31	113	89	24	113	87	26	115	88	27
30. Fla. (incl. FSU/FAMUprogram)	120	94	26	116	89	27	115	85	30	116	85	31
31. Florida, South	75	64	11	96	80	16	97	76	21	96	79	17
32. Georgetown	210	168	42	210	170	40	208	164	44	205	159	46
33. George Washington	152	108	44	152	116	36	153	105	48	155	114	41
34. Gebrgia	184	140	44	189	158	31	190	148	42	181	151	30
35. Hahnemann	182	145	37	192	150	42	187	138	49	192	145	47
36. Harvard	165	106	59	170	115	55	166	112	54	167	121	46
37. Hawaii	66	45	21	66	49	17	67	47	20	68	53	15
38. Howard	134	90	44	132	92	40	136	91	45	139	83	56
39. Illinois	349	270	79	343	256	87	342	270	72	344	264	80
40. Illinois, Southern	70	59	11	78	54	24	73	55	18	74	61	13
41. Indiana	318	262	56	316	238	78	319	237	82	320	253	67
42. Iowa	177	143	34	176	135	41	179	124	55	175	133	42
43. Jefferson	229	182	47	227	179	48	230	189	41	235	193	42
44. Johns Hopkins	122	99	23	120	97	23	120	99	21	121	104	17
45. Kansas	218	189	29	206	154	52	217	170	47	202	164	38
46. Kentucky	113	87	26	110	86	24	110	77	33	110	84	26
47. Loma Linda	175	135	40	166	136	30	162	127	35	149	113	36
48. Louisiana--New Orleans	182	152	30	188	160	28	184	151	33	183	148	35
49. Louisiana--Shreveport	97	81	16	98	79	19	102	90	12	106	85	21
50. Louisville	135	105	30	138	103	35	141	106	35	135	106	29
51. Loyola--Stritch	136	100	36	150	111	39	150	108	42	153	109	44
52. Marshall	-	-	-	-	-	-	24	20	4	26	19	7
53. Maryland	173	131	42	184	137	47	177	130	47	181	144	37
54. Massachusetts	102	77	25	102	70	32	104	71	33	104	76	28
55. Mayo	40	30	10	41	32	9	40	26	14	41	34	7
56. Meharry	126	94	32	135	92	43	149	114	35	149	100	49
57. Miami	162	136	26	133	108	25	139	114	25	144	111	33
58. Michigan State	105	65	40	105	66	39	110	70	40	117	74	43
59. Michigan, U. of	247	175	72	242	174	68	245	182	63	247	172	75
60. Minnesota--Duluth	36	32	4	36	30	6	48	37	11	48	36	12
61. Minnesota--Minneapolis	248	199	49	246	194	52	248	192	56	243	178	65
62. Mississippi	151	122	29	154	117	37	152	123	29	154	129	25
63. Missouri--Columbia	114	87	27	118	100	18	113	96	17	113	87	26
64. Missouri--Kansas City	61	39	22	75	47	28	80	44	36	83	47	36
65. Morehouse	-	-	-	-	-	-	-	-	-	24	14	10

U.S. MEDICAL SCHOOL FIRST-YEAR ENROLLMENT BY SEX
(Continued)

	75-76			76-77			77-78			78-79		
	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women
66. Mount Sinai	85	67	18	104	72	32	104	73	31	102	65	37
67. Nebraska	155	130	25	165	131	34	183	127	56	152	113	39
68. Nevada--Reno	48	39	9	48	38	10	49	35	14	49	35	14
69. New Jersey:CMDNJ N.J.Med.	119	88	31	116	83	33	115	76	39	154	110	44
70. Rutgers	111	72	39	113	78	35	115	78	37	114	84	30
71. New Mexico	78	63	15	78	53	25	76	52	24	75	53	22
72. New York Medical	180	123	57	180	130	50	180	125	55	180	134	46
73. New York University	171	120	51	173	125	48	174	121	53	171	132	39
74. New York: SUNY Buffalo	144	96	48	139	95	44	142	94	48	142	94	48
75. Downstate	224	166	58	221	165	56	223	164	59	221	168	53
76. Stony Brook	47	24	23	50	24	26	61	39	22	63	44	19
77. Upstate	124	88	36	125	86	39	140	109	31	150	109	41
78. North Carolina	140	109	31	161	115	46	160	108	52	161	111	50
79. North Dakota	68	56	12	68	54	14	67	54	13	67	55	12
80. Northwestern	171	129	42	174	127	47	173	117	56	177	117	60
81. Ohio, Medical College of	100	72	28	117	92	25	121	88	33	133	93	40
82. Ohio, Northeastern	-	-	-	-	-	-	48	36	12	49	31	18
83. Ohio State	243	198	45	242	189	53	251	197	54	251	197	54
84. Oklahoma	168	145	23	177	143	34	177	141	36	178	138	40
85. Oregon	115	91	24	115	94	21	116	86	30	117	85	32
86. Penn., Med. College of	106	39	67	114	43	71	106	35	71	102	40	62
87. Pennsylvania State	101	77	24	98	75	23	95	74	21	97	71	26
88. Pennsylvania, U. of	160	116	44	160	114	46	160	113	47	160	119	41
89. Pittsburgh	138	102	36	139	106	33	139	108	31	136	107	29
90. Puerto Rico, Cath. U. of	-	-	-	-	-	-	26	21	5	28	20	8
91. Puerto Rico, U. of	135	89	46	143	103	40	150	95	55	155	84	71
92. Rochester	98	72	26	97	68	29	98	71	27	101	69	32
93. Rush	112	80	32	120	73	47	120	75	45	122	83	39
94. Saint Louis	162	135	27	157	132	25	155	129	26	155	117	38
95. S.Carolina, Med.U. of	175	147	28	172	140	32	168	138	30	169	130	39
96. S.Carolina, U. of	-	-	-	-	-	-	24	22	2	37	32	5
97. South Dakota	65	30	15	65	54	11	76	61	15	68	56	12
98. Stanford	86	59	27	87	58	29	86	54	32	86	59	27
99. Temple	186	148	38	184	142	42	184	126	58	184	125	59
100. Tennessee, U. of	209	175	34	211	175	36	210	171	39	221	187	34
101. Tennessee, East	-	-	-	-	-	-	-	-	-	24	18	6
102. Texas A&M	-	-	-	-	-	-	32	25	7	32	28	4
103. Texas, U. of Dallas,S.W.	202	169	33	205	176	29	208	171	37	207	172	35
104. Galveston	206	160	46	206	165	41	206	149	57	208	151	57
105. Houston	67	51	16	100	83	17	165	137	28	159	119	40
106. San Antonio	126	95	31	140	95	45	145	105	40	214	161	53
107. Texas Tech.	44	38	6	40	34	6	43	33	10	62	50	12
108. Tufts	150	99	51	152	105	47	149	102	47	151	104	47
109. Tulane	149	116	33	150	122	28	151	115	36	150	117	33
110. Uniformed Services Univ.	-	-	-	32	27	5	68	52	16	108	87	21
111. Utah	101	87	14	100	91	9	100	85	15	102	83	19
112. Vanderbilt	83	64	19	83	69	14	104	83	21	104	88	16
113. Vermont	85	65	20	83	62	21	84	70	14	83	62	21
114. Virginia, Eastern	49	35	14	65	42	23	65	52	13	80	59	21
115. Virginia,Med. College of	169	132	37	168	125	43	168	119	49	168	137	31
116. Virginia, U. of	139	110	29	138	112	26	139	112	27	138	108	30
117. Washington U. (St. Louis)	129	101	28	126	97	29	127	93	34	128	97	31
118. Washington, U. of	175	125	50	175	134	41	175	133	42	175	123	52
119. Wayne State	261	205	56	256	206	50	256	208	48	256	196	60
120. West Virginia	84	67	17	88	75	13	89	69	20	88	68	20
121. Wisconsin, Med.College of	125	100	25	136	104	32	151	122	29	180	135	45
122. Wisconsin, U. of	159	126	33	163	120	43	167	115	52	168	135	33
123. Wright State	-	-	-	32	22	10	50	36	14	79	58	21
124. Yale	102	74	28	102	73	29	102	74	28	102	69	33
TOTAL	15351	11695	3656	15667	11791	3876	16134	11985	4149	16501	12339	4162

Sources: JAMA: Medical Education in the United States, 1975-1976, 1976-1977, 1977-1978.

AAMC: Medical Admission Requirements, 1980-1981.

APPENDIX B

USING PHYSICIAN SUPPLY MODELS:

COMPUTATIONAL CONSIDERATIONS

USING PHYSICIAN SUPPLY MODELS: COMPUTATIONAL CONSIDERATIONS

L. G. Hunt

Physician supply models are used to answer questions on the future availability of medical services. A typical question is: Will there be enough (or too many) physicians practicing a given specialty in some future year?

Supply models are prospective. That is, they take data on the current numbers of practicing physicians, their death and retirement rates, future numbers of medical school graduates, and the distribution of their residency choices and predict supply in future years. Since their function is only to forecast the results of their inputs, these models do not tell us how to go about achieving any particular supply goal. Suppose current policy (e.g., Federal support of primary care residencies) leads to an oversupply or undersupply in a given specialty. What can be done about it? Prospective models cannot tell us directly. They can only be used iteratively to help us guess the input changes necessary to obtain the desired supply outputs.

A more systematic approach is to devise a "backwards" model which starts with the outputs of the prospective model and calculates the change in its inputs necessary to achieve the desired supply. Such a model need not be exact since its only purpose is to guide our manipulation of the prospective model's inputs. We are therefore willing to make various simplifying assumptions which make the backwards model easier to use. One of these is a constant loss rate for each pool of practicing specialists.

Under this assumption, the basic equation for pool size, P_n, (of a given specialty) in some future year n is:

$$P_n = Bs^n + A_1 s^{n-1} + A_2 s^{n-2} + \ldots + A_{n-1} s + A_n = Bs^n + \sum_{i=1}^{n} A_i s^{n-i}$$

where B is the size of the base year pool, s is the average annual survival probability, and A_i is the GME output (to the given specialty) in the i^{th} year ($i = 1, \ldots, n$). We see that the population in year n, P_n, consists of n + 1 increments -- the survivors of the base year's pool (B) plus those resulting from the GME output cohorts in each year starting from the base year through year n (the A_i).

Since the losses through death and retirement in each of the i^{th} year cohorts is approximately geometric (s^{n-i}), the contributions of the earlier groups to P_n progressively decrease with passing time. Thus, in general, changes in the earlier GME outputs will have less relative effect on P_n than later ones.

Suppose P_n is too large (or too small), and we wish to reduce (increase) it by an amount ΔP_n. Then

$$P_n + \Delta P_n = Bs^n + \sum_{i=1}^{n} A_i s^{n-i} + \Delta P_n$$

where ΔP_n may be either positive or negative, depending on whether an increased or decreased pool is desired.

Since Bs^n (the n^{th}-year residue of the original pool) is fixed, only the A_i terms can be modified to adjust the output. There are obviously many

ways of modifying these terms to obtain the desired modification ΔP_n, but there are several reasonable choices. For example, it would be convenient (if it is possible) to modify each year's GME output by the same amount: $\Delta A = \Delta A_i$, $i = 1, 2, \ldots, n$. In this case,

$$\Delta P_n = \Delta A_1 s^{n-1} + \Delta A_2 s^{n-2} + \ldots + \Delta A_{n-1} s + \Delta A_n = \Delta A \left[\frac{1-s^n}{1-s}\right]$$

from which we obtain the desired annual change

$$\Delta A = \Delta P_n \left[\frac{1-s}{1-s^n}\right].$$

What is the implication of applying a constant modification, ΔA, to each year's output? Note that each A_i may be expressed as the sum of the current and the preceding years' outputs for all residencies that feed the specialty being considered; that is to say,

$$A_i = \sum_k \sum_j f_{kj} R_{i-k,j}$$

where $R_{i-k,j}$ is the first-year input into the j^{th} residency program in year i-k, and f_{kj} is the fraction of those individuals who enter practice (within the specialty pool we wish to modify) following their k^{th} year of GME.

Generally (though not always), the major part of each A_i will come from its "parent" residency program -- for instance, most pediatricians come from pediatrics residencies -- so it will be convenient to separate the parent residency j* from the remaining values of j:

$$A_i = \sum_k f_{kj*} R_{i-k,j*} + \sum_k \sum_{j \neq j*} f_{kj} R_{i-k,j}$$

Now we can distribute the desired modification, ΔA, over the first summation (involving the specialty of interest) without interfering with the other residency programs which "feed" that specialty. To do this, we note that the first summation involves only those values of k for which $f_{kj^*} > 0$. Suppose there are N such values; if we divide ΔA evenly over all such years, we end up modifying the first summation as follows:[1]

$$\sum_k f_k R_{i-k} + \Delta A = \sum_k (f_k R_{i-k} + \frac{\Delta A}{N})$$

$$= \sum_k f_k (R_{i-k} + \frac{\Delta A}{N f_k})$$

This form of modification to each year's residency input (R_{i-k}) will achieve the desired change in output (A_1). But how will it affect P_n? Since

$$P_n + \Delta P_n = Bs^n + (A_1 + \Delta A)s^{n-1} + (A_2 + \Delta A)s^{n-2} + \ldots + (A_n + \Delta A)$$

$$= Bs^n + [\sum_k f_k (R_{1-k} + \frac{\Delta A}{N f_k} + \Sigma\Sigma] s^{n-1} + [\sum_k f_k (R_{2-k} + \frac{\Delta A}{N f_k}) + \Sigma\Sigma] s^{n-2}$$

$$+ \ldots$$

there is immediately a difficulty because this equation requires us to modify the same R_i in a different way in each term. For instance, in

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[1] At this point, the subscript j* can be dropped. All specialty references will be understood to apply to j*.

the first set of brackets (corresponding to the first year of GME output subsequent to the base year), we have the following series of terms:

$$f_0(R_1 + \frac{\Delta A}{Nf_0}),\ f_1(R_0 + \frac{\Delta A}{Nf_1}),\ f_2(R_{-1} + \frac{\Delta A}{Nf_2}),\ \ldots$$

while in the second set of brackets, the leading terms are as follows:

$$f_0(R_2 + \frac{\Delta A}{Nf_0}),\ f_1(R_1 + \frac{\Delta A}{Nf_1}),\ f_2(R_0 + \frac{\Delta A}{Nf_2}),\ \ldots$$

Note the inconsistency: in the first set of terms, we are obliged to modify R_1 by $\Delta A/Nf_0$; in the second set, the prescribed modification is $\Delta A/Nf_1$. Unless $f_0 = f_1$ (not the usual case), we <u>can't do both</u>; each year's residency input can only be changed once.

What is the alternative? Another approach is to make a constant <u>percentage</u> change in each A_i. If $\Delta P_n/P_n$ is the desired fractional change, then $(P_n + \Delta P_n)/P_n = p$ is the required <u>new</u> fraction (which may be either greater or less than 1.0). However, we cannot apply p equally to all of the terms in P_n since

$$P_n + \Delta P_n = pP_n = p[Bs^n + \sum_{i=1}^{n} A_i s^{n-i}]$$

would cause the base year pool to be changed to pBs^n which, of course, we cannot tolerate since Bs^n is fixed.

However, adding and subtracting $(1-p)Bs^n$ gives

$$pP_n = pBs^n + (1-p)Bs^n + p\sum_{i=1}^{n} A_i s^{n-i} - (1-p)Bs^n$$

$$= Bs^n + p\Sigma[A_i s^{n-i} - \frac{(1-p)Bs^n}{np}]$$

$$= Bs^n + \Sigma[pA_i s^{n-i} - \frac{(1-p)Bs^n}{n}]$$

$$= Bs^n + \Sigma pA_i s^{n-i}(1-k_i)$$

where $k_i = \frac{(1-p)Bs^i}{pA_i n}$.

Thus we can obtain the required change in P_n by multiplying each $A_i s^{n-i}$ by $p_i^* = p(1-k_i)$. A complication is that p_i^* is a function of i and in particular is dependent on the term s^i. However, for the GME output cohorts, s is nearly 1.0 and even s^{12} (i.e., survival from 1978 to 1990) is about .99 for males.[1] We can take an average of p_i^* without much error:

$$\bar{p}^* = \frac{1}{n}\sum_i p_i^*.$$

Thus finally

$$P_n + \Delta P_n = pP_n \simeq Bs^n + \bar{p}^*\Sigma A_i s^{n-i}$$

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[1] Note that this simplification is reasonable only for the GME output cohorts (because of their age). For the active pool, smaller values of s would apply.

This result is crucial because it means that all the values of A_i are modified by a constant multiple, which in turn means that each year's residency input R_k is also modified the same way, because

$$\bar{p}^* A_i = \bar{p}^* \sum_k f_{kj^*} R_{i-k,j^*} + \bar{p}^* \sum_k \sum_{j \neq j^*} f_{kj} R_{i-k,j}$$

If nearly all of a specialty comes from its parent residency, we can ignore the second term without much effect. If not, we can modify $\bar{p}^*$ further by noting that the first summation (Σ) represents the portion of the GME output cohort which comes from the parent residency, while the second summation ($\Sigma_k \Sigma_{j \neq j^*}$) represents the portion which comes from other specialties. If we define

$$\Sigma_k / A_i = r$$

it follows that

$$\Sigma_k \Sigma_{j \neq j^*} / A_i = 1-r$$

since all members of a given cohort must either come from the parent residency or elsewhere. Σ is to $\Sigma\Sigma$, therefore, as r is to 1-r.

If we now multiply A_i by $\bar{p}^*$, we can perform the following simplifications:

$$\bar{p}^*A_i = \bar{p}^*\Sigma + \bar{p}^*\Sigma\Sigma$$

$$= \bar{p}^*\Sigma - \Sigma\Sigma + \bar{p}^*\Sigma\Sigma + \Sigma\Sigma$$

$$= \bar{p}^*\Sigma - \frac{(1-r)\Sigma}{r} + \frac{\bar{p}^*(1-r)\Sigma}{r} + \Sigma\Sigma$$

$$= [\bar{p}^* - \frac{(1-r)}{r} + \frac{\bar{p}^*(1-r)}{r}]\Sigma + \Sigma\Sigma$$

$$= [\frac{r-1+\bar{p}^*}{r}]\Sigma + \Sigma\Sigma$$

Now the entire effect of the change in output is due to modifying the original inputs to the parent residencies by a constant factor

$$(\frac{r + \bar{p}^* - 1}{r})$$

instead of $\bar{p}^*$, by using r, the fraction of the specialty which originates in its own residency program.

To summarize, this discussion shows that it is not feasible to alter the size of a specialty pool by changing preceding years' residency inputs by equal numbers. It is possible to obtain (approximately) a desired output change by adjusting each residency input by the same percentage. Moreover, this percentage can itself be adjusted and applied in such a way that the total output change is assigned to the parent residency and thus does not interfere with the outputs of the other residencies which supply the specialty being modified.

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